CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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CALIFORNIA FISH AND GAME

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ECONOMIC VALUES OF STRIPED BASS, SALMON, AND STEELHEAD SPORT FISHING IN CALIFORNIA[1]

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INTRODUCTION

Plans for controlling the Sacramento and San Joaquin rivers by placing a barrier across San Francisco Bay have captured the imagination of water-conscious Californians for generations. The State of California, through the San Francisco Bay Salinity Control Barrier Investigation, is currently studying the feasibility of a multipurpose barrier across the northern arm of San Francisco Bay. Unfortunately, such a barrier would be a severe hazard to migratory fishes entering the Sacramento-San Joaquin rivers. The present survey was designed to assign economic values to California's sport fisheries for striped bass, salmon, and steelhead, for comparison with other costs and benefits of the project.

Fisheries administrators are continually faced with the problem of proposed new dams that will interfere with the migration or reproduction of fishes. These problems are especially acute in coastal areas, as the river to be dammed frequently contains several species of anadromous fishes whose migration route would be blocked.

The agency or company interested in the construction of the dam is usually able to describe its benefits in tangible terms. The value of a kilowatt, or of an acre-foot of water, is easily put in terms of dollars and cents. The fisheries administrator, on the other hand, may be able to argue convincingly that a run of fish faces destruction, but faces a difficult task when he is asked to evaluate the fishery in monetary terms. Such an evaluation is usually necessary to insure the inclusion of adequate fish protective facilities at the dam. Moreover, in instances in which fish protective devices are not feasible, the value of the fishery facing destruction may be even greater than the benefits to be derived from the project.

If the species is one that is subject to commercial exploitation, the commercial value is not difficult to obtain. Most commercial fisheries are required to maintain catch records and to file them with a governmental agency, which tabulates and makes them available to interested parties. If the fishery in question is subject to sport fishing, the problem becomes more difficult. Frequently the magnitude of the sport fishery is not known, and even when it is known the problem of expressing its value in terms of dollars and cents is difficult.

[1] Submitted for publication September, 1954.

In recent years several efforts have been made to express the values of sport fisheries in monetary terms. Wallace (1952), Ballaine and Fiekowsky (1953), and Stains and Barkalow (1951) have determined the value of fisheries on a state-wide basis in Washington, Oregon, and North Carolina, respectively. Bennett and Durham (1951) described the value of largemouth black bass in a single lake in Illinois. The River Basins Section of the U. S. Fish and Wildlife Service has frequently evaluated sport fisheries in connection with federal power and irrigation dams. These writers have used different methods of determining values, and have expressed these values in equally different terms.

The California Department of Fish and Game for some time has taken the stand that the most reasonable manner of expressing the value of a sport fishery is in terms of the average cost to an angler of a single day's fishing. Such a value has a solid economic basis, and is readily understood by a person unfamiliar with the fishery. This unit of value has been chosen in place of an evaluation in terms of cost per pound of fish or per individual fish, which tends to emphasize the meat value as opposed to the recreational value of a sport fishery. An expression of value on a poundage or fish basis encourages comparison with the market value of the fish. In such a comparison the cost figures are frequently so high as to defy common sense, and the primary recreational value is glossed over.

The values of wildlife resources are practically intangible, and their many aesthetic qualities are not subject to economic evaluation. The amount of money that people spend in hunting and fishing simply reflects the importance of these values. In determining values in this analysis the assumption has been made that if an angler is willing to spend a certain amount of money for a day's fishing, the fishing has been worth that amount to him from the standpoint of recreation. Therefore, the value of one angler day is taken as the average amount spent on a day's fishing by the average angler. Assignment of this value to a particular fishery is further justified in that it represents money actually spent on the fishery.

METHODS

Selecting the Sample

The cost figures outlined in this paper were determined by means of questionnaires sent to persons who were known to have fished for the species involved. The sample of respondents was selected from persons replying to the regular state-wide 1953 postal card questionnaire (Skinner, 1955). These postal card surveys have been described in detail by Calhoun (1950).

In the 1953 survey, 9,323 postal card questionnaires were sent to a representative sample of angling licensees.[2] Since the returned portion of the postal card questionnaire does not show the name and address of the respondent, it was necessary to code some of the return cards so that this information could be obtained. Every third card was

[2] The tenth stub in each fifth book of 25 licenses was selected.

selected and coded, giving a total of 3,113. In the 1953 survey, 3,127 postal cards were returned (33.5 percent), of which 1,028 were coded cards from known respondents.

Of these latter cards 330 reported angling for striped bass, salmon, or steelhead and constituted the sample for the economic survey. It included 162 striped bass anglers, 117 salmon anglers, and 51 steelhead anglers. A letter and questionnaire (Forms 1 and 2 in Appendix) were sent to each of them.

The mailing of questionnaires began on January 21, 1954, and returns received through April 15, 1954, were used. The few questionnaires returned after that date were disregarded, and are not included in the present study. All of the anglers who did not return the questionnaire after three weeks were sent follow-up letters (Form 3 in Appendix) and a duplicate questionnaire.

Of the 330 questionnaires mailed, 297 (90 percent) were returned. Incomplete replies and contradictory statements made 25 of the returns unusable.

Processing the Returns

In processing the questionnaires, the expenditures were broken down into five categories: transportation, food and lodging, services and supplies, equipment, and cost of license. The services and supplies category includes fees and items that are a part of each fishing trip, or that last at most for one year. The equipment category includes items that are normally expected to last longer than one year.

The estimates of the period of usefulness of equipment items in Table 1 are based on a survey conducted among personnel of the Department of Fish and Game and information contained in two papers (Bennett and Durham, op. cit.; U. S. Fish and Wildlife Service, 1951).

TABLE 1

The Estimated Period of Usefulness of Fishing Equipment Used in Amortizing the Cost of the Equipment

Item	*Period of usefulness (Years)*
Rods	10
Reels	8
Plugs and other lures	1
Tackle box	7
Gaff hook	8
Landing net	3
Boat	10
Outboard motor	6
Gas can	4
Boat trailer	10
Fishing line	2
Special clothing	4

Since certain items of equipment may be used for several different types of fishing, the respondents were asked to list the fraction of time that each piece of equipment was used for the type of fishing in question (see Question 8 of Appendix, Form 2). In this manner, it was possible to assign charges to only the fraction of use in that fishery.

Automobile transportation costs were based on a figure of 7½ cents per mile. The total mileage figure was charged as an expense of the

angler reporting the mileage. Anglers not using their own automobile for fishing trips (i.e., traveling with others) and reporting zero miles compensate for the fact that there is usually more than one person riding in an automobile on such trips.

The amount charged to angling licenses was arrived at by dividing the cost of the license by the number of days fished for all types of fish and multiplying that figure by the number of days spent angling for the species in question. The cost of a California resident angling license is $3.

RESULTS

Striped Bass

Of the 162 questionnaires sent to striped bass anglers, 89.5 percent were returned. The characteristics of the striped bass sample are shown in Table 2.

TABLE 2

Characteristics of the Striped Bass Sample

Number of questionnaires sent	162
Number of questionnaires returned	145
Usable questionnaires	130
Unusable questionnaires	15
Mean number of days fished per angler	15.6
Mean number of fish caught per angler	10.5

The total expenditure of the 130 reporting anglers in the sample was $18,618.95. The mean annual expenditure of these anglers was $143.22. The mean expenditure per angler day was $9.18. The range of individual angler-day expenditures was from $0.50 to $54.02 (computed for each angler on a yearly basis). Table 3 shows the distribution of annual expenditures of striped bass anglers included in the survey. The standard error of the mean annual expenditure for this sample was $12.72.

TABLE 3

Annual Expenditures of California Striped Bass Anglers in 1953

Expenditures	*Number of anglers*	*Expenditures*	*Number of anglers*
$0-$40	31	$360-$400	2
40- 80	23	400- 440	1
80-120	19	440- 480	1
120-160	14	480- 520	0
160-200	10	520- 560	1
200-240	12	560- 600	1
240-280	5	Over 600	2 *
280-320	5		
320-360	3	Total	130

* $771.56 and $955.16.

The 130 anglers returning usable questionnaires reported a total of 2,027 days of angling, and a total catch of 1,364 fish. The mean reported weight of the striped bass caught was 4.8 pounds.

Although the writer prefers the expression of value in terms of angler days rather than pounds of fish, the latter value is of interest and might be useful for comparative purposes. The value obtained was $2.85 per pound of striped bass, or $13.66 per individual fish.

Since an estimated 2,000,000 days were spent angling for striped bass in California during 1953 (Skinner, op. cit.), and the mean daily expenditure was $9 (rounded from $9.18), the total recreational value of the fishery for that year was on the order of $18,000,000.

Salmon

Of the 117 questionnaires sent to salmon anglers, 88 percent were returned. The characteristics of the sample of salmon anglers are shown in Table 4.

TABLE 4

Characteristics of the Salmon Sample

Number of questionnaires sent	117
Number of questionnaires returned	103
Usable questionnaires	96
Unusable questionnaires	7
Mean number of days fished per angler	7.1
Mean number of fish caught per angler	6.8

The total expenditure of salmon anglers in the sample was $10,955.76, representing a mean annual expenditure of $114.12, and a mean daily expenditure of $16.09. The range of individual angler-day expenditures was from $1.15 to $136.57. The frequency distribution of annual expenditures is shown in Table 5. The standard error of the mean annual expenditure for this sample is $15.93.

TABLE 5

Annual Expenditures of California Salmon Anglers in 1953

Expenditures	*Number of anglers*
$0-$40	33
40- 80	23
80-120	12
120-160	10
160-200	4
200-240	3
240-280	2
280-320	1
320-360	1
360-400	2
400-440	1
440-480	1
480-520	1
Over 520	2*
Total	96

* $725.76 and $1,045.88.

The salmon anglers in the sample spent 681 days fishing, and caught 650 fish with a mean reported weight of 12.3 pounds. This represents an expenditure of $1.38 per pound or $16.85 per fish.

With an estimated 650,000 days spent angling for salmon in California in 1953, and a mean daily expenditure of $16 (rounded from $16.09) the total recreational value of the sport fishery that year was on the order of $10,400,000.

Steelhead

The return from 51 questionnaires sent to steelhead anglers was 96 percent. The characteristics of the sample of steelhead anglers are shown in Table 6.

TABLE 6

Characteristics of the Steelhead Sample

Number of questionnaires sent	51
Number of questionnaires returned	49
Usable questionnaires	46
Unusable questionnaires	3
Mean number of days fished per angler	7.6
Mean number of fish caught per angler	4.6

The total expenditure of steelhead anglers included in the sample was $6,359.12, representing a mean annual expenditure of $138.24, and a mean daily expenditure of $18.11. The individual angler-day expenditures ranged from $0.51 to $109.91. The frequency distribution of annual expenditures is shown in Table 7. The standard error of the mean annual expenditure for this sample is $16.30.

TABLE 7

Annual Expenditures of California Steelhead Anglers in 1953

Expenditures	*Number of anglers*
$0-$40	8
40- 80	10
80-120	10
120-160	3
160-200	4
200-240	2
240-280	3
280-320	1
320-360	3
Over 360	2*
Total	46

* $470.91 and $543.14.

The 46 reporting steelhead anglers spent 351 days fishing and caught 225 fish averaging 5.1 pounds each, representing an expenditure of $5.58 per pound and $28.26 per fish.

Since an estimated 410,000 days were spent angling for steelhead in California in 1953, and the mean daily expenditure was $18 (rounded from $18.11), the total recreational value of the steelhead fishery for that year was on the order of $7,380,000.

DISCUSSION

Limitations of the Survey

In a survey of this sort, in which a small representative sample is selected to provide information regarding a large group, there are several possible weaknesses.

The selection of this sample was based on a 33.5 percent response to postal card questionnaires regarding catches of fish during 1953.

This third is taken to represent the whole group, and the respondents for the economic survey were selected from it. Calhoun (op. cit.) found no significant differences between respondents and nonrespondents with respect to reported catches, and Hjersman (1951) found a similar situation with respect to game reports. In both of these cases, only catches or bags were considered, and no questions regarding expenditures were asked.

Wallace (op. cit.), in a survey of the hunting and fishing expenditures of Washington sportsmen, noted that persons failing to respond to the original request for information reported lower expenditures after a follow-up letter was sent to them. Telephone calls or personal contacts brought returns similar to those obtained after the follow-up letter. He strongly emphasized the importance of following up in this type of survey.

In the present study a follow-up letter was sent to persons failing to respond to the first request for information. It was found that these tardy respondents spent less than those replying to the first request. In the case of striped bass anglers the group replying to the first request (84 anglers) had a mean daily expenditure of $10.40, while the group replying after the follow-up letter (46 anglers) averaged $7.54 per day. Results from the salmon and steelhead anglers were similar. This difference in the two groups agrees with the findings of Wallace (op. cit.) and re-emphasizes the importance of a follow-up letter in this type of survey.

At first glance it appears that conflicting results were obtained with respect to nonresponse. The two surveys concerned with catches found nonrespondents to be similar to respondents, while the two surveys concerned with expenditures showed nonrespondents to have different characteristics from those responding to the first request. It is possible that the difference in type of information sought is responsible for the different characteristics of the nonrespondents. So little is known regarding the effects of nonresponse that it is impossible to assess the significance of this weakness. Being based on a one-third response to a catch survey questionnaire, the estimates in this analysis may be slightly exaggerated.

Other possible weaknesses are the fact that the study is based on recollection rather than records of expenditures; persons under 16 years of age need no angling license, and were therefore not included in our sample; and only one phase of angling was considered, which might make it difficult to allocate expenses in the case of joint angling trips.

Distribution of Expenditures

Figure 1 shows the distribution of expenditures among the categories of transportation, food and lodging, services and supplies, equipment, and license.

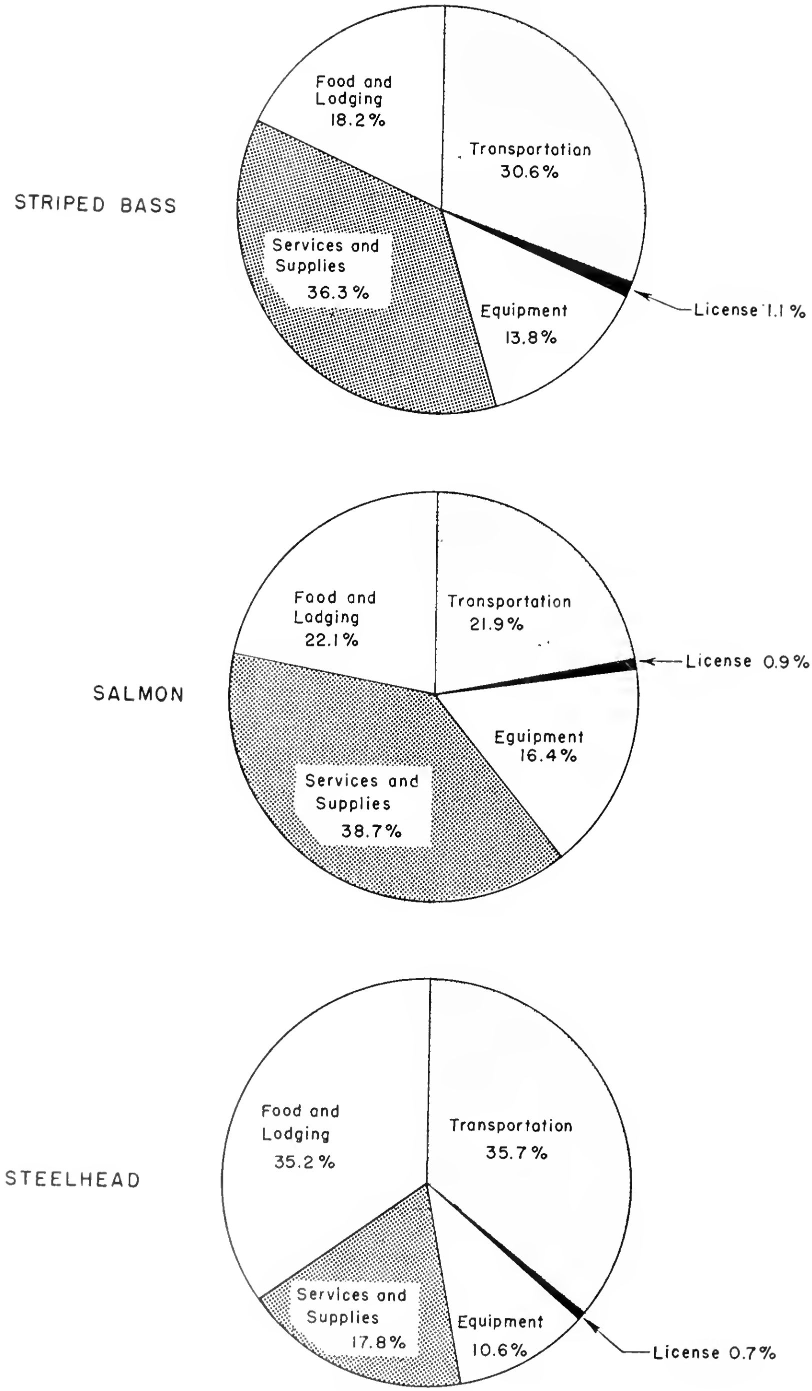

FIGURE 1. The distribution of expenditures by striped bass, salmon, and steelhead anglers.

Striped bass anglers distribute their expenditures fairly evenly among the components excepting, of course, licenses, which are a minor item in all of the types of fishing included in the survey. Services and supplies and transportation are the major items with striped bass anglers. This is readily understandable, since this fishery is restricted to central California and thus attracts many people who drive long distances. Moreover, boat rental and bait costs are high, and terminal gear is lost frequently, adding to the cost of services and supplies.

Services and supplies were the major items for salmon anglers, no doubt because much of the fishing is done from party boats. The cost of a party boat trip is from $5 to $10.

Steelhead anglers generally drive long distances from centers of population to the sparsely populated north coastal region, resulting in large expenditures for transportation and for food and lodging.

Size Distribution

Figure 2 shows the size distribution of the state-wide striped bass, salmon, and steelhead sport catches, based on this survey. This is the first time that such estimates have become available for any of these fisheries.

Although the questionnaire was worded to prevent the inclusion of sub-legal fish, it is probable that the smaller size group in the case of striped bass and salmon includes such fish.

ACKNOWLEDGMENTS

I wish to thank Miss Alice Matsuhara, who devoted a great deal of time and effort to the clerical portion of the survey.

SUMMARY

The average expenditure per angler day is considered a good measure of the economic value of a sport fishery.

Questionnaires were sent to random samples of California striped bass, salmon, and steelhead anglers to determine their average expenditures per day of angling for these fish in 1953.

Striped bass anglers spent an average of $9 per angler day. The estimated value of this fishery in 1953 was $18,000,000.

Salmon anglers spent an average of $16 per angler day. This sport fishery had an estimated value of $10,400,000 in 1953.

Steelhead anglers spent an average of $18 per angler day. The 1953 value of this fishery was $7,380,000.

The distribution of expenditures into several categories shows transportation, food and lodging, and services and supplies to be major items for the types of angling under study. License costs amounted to only about one percent of total costs in each case.

The average sizes of the fish reported caught by respondents were: striped bass, 4.8 pounds; salmon, 12.3 pounds; steelhead, 5.1 pounds.

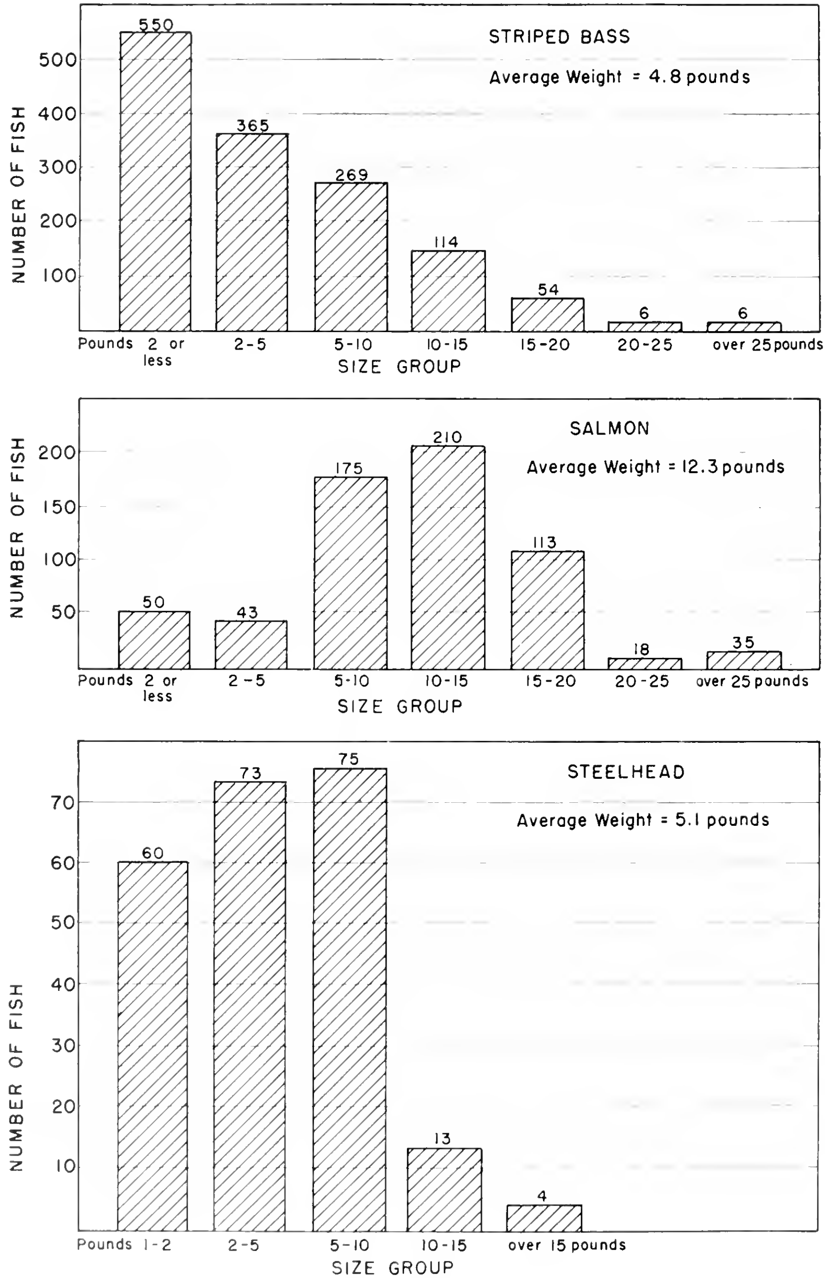

FIGURE 2. The size distribution of the striped bass, salmon, and steelhead reported caught.

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APPENDIX

The forms shown are those used for striped bass. The salmon and steelhead angler forms were virtually identical.

FORM 1

The Letter Sent to Anglers Along With the Questionnaire

The Department of Fish and Game is collecting economic information regarding striped bass fishing in California. It is very important that we know the value of this fishery, so that it can be compared with the values of other resources and developments in central California.

Our postal card survey gives us reliable estimates of the total number of days anglers spend in striped bass fishing each year. If we can determine the average cost of a day's striper fishing we will be able to estimate the total value of the fishery.

Questionnaires are being sent to several hundred California anglers whose names were drawn at random from those of all 1953 California angling license holders. Because you are one of this special group you are, in effect, representing 5,625 other anglers. You can see that accurate answers from you are very important.

Will you please help us in our efforts to maintain and improve angling by filling in the questionnaire and returning it in the enclosed envelope. You may rest assured that all information given will be held in strict confidence.

Thank you for your cooperation.

Sincerely yours,

SETH GORDON, Director

FORM 2

Striped Bass Questionnaire

Name ______________________

Address ______________________

____

1. How many days did you fish for striped bass in California in 1953?

_______ days in the vicinity of ______________

_______ days in the vicinity of ______________

_______ days in the vicinity of ______________

_______ days in the vicinity of ______________

_______ Total number of days.

2. List, as accurately as you can, the number of striped bass of each of the following size groups that you caught during 1953. (Do not include any undersize fish that you might have caught.)

_______ fish of 2 pounds or less

_______ fish from 2 to 5 pounds

_______ fish from 5 to 10 pounds

_______ fish from 10 to 15 pounds

_______ fish from 15 to 20 pounds

Over 20 pounds—specify individual weights

_______ _______

_______ _______

_______ _______

_______ _______

3. Approximately what was the total number of miles you drove *your* automobile on striped bass fishing trips in 1953? (Do not include automobile trips in cars of others.)

_______ miles.

4. What were your other transportation expenses (train, bus, etc.) that may be directly charged to striped bass fishing?

____

5. If you stayed overnight on any of your striped bass fishing trips, how much did you spend for such lodging during the entire year?

____

6. How much did you spend on meals and refreshments during your striped bass fishing trips in 1953?

____

7. What is your best estimate of your last year's striped bass fishing expenditures not already listed? For your aid in recollecting these 1953 expenditures you might use the following list:

Operating expenses:

Bait ______________ $_______

Outboard rental ______________ _______

Outboard fuel ______________ _______

FORM 2—Continued
Striped Bass Questionnaire

Outboard upkeep (if your own)	______
Boat rental	______
Boat operation (other than outboard)	______
Boat upkeep (if your own)	______
Moorage rental	______
Party boat fees	______
Film (used on striped bass fishing trips)	______
Telephone	______
Expendable tackle (hooks, leaders, sinkers, etc.)	______
Other (please specify)	______
______	______
______	______

8. *Equipment.* List the total cost of the equipment you now use for striped bass fishing. We will compute the amount that may be charged to 1953 striped bass fishing from the average life of this equipment.

   If the equipment is used for other types of fishing as well as striped bass fishing, list the *fraction of time that it is used for striped bass fishing.* For example: If you have a twenty-dollar rod that is used about half of the time for striped bass and half time for deep-sea fishing, list the value as twenty dollars; and in the column marked "Fraction of time used for striped bass fishing" place the fraction $\frac{1}{2}$. If you went striped bass fishing four times and deep-sea fishing only once, the fraction would be $\frac{4}{5}$. If the equipment is used for striped bass fishing only, place the word "all" in the fraction column.

Equipment	*Cost when new*	*Fraction of time used for striped bass fishing*
Rods	\$______	______
Reels	______	______
Plugs and other lures	______	______
Tackle box	______	______
Gaff hook	______	______
Landing net	______	______
Boat	______	______
Outboard motor	______	______
Gas can	______	______
Boat trailer	______	______
Fishing line	______	______
Special clothing	______	______
Other (please specify)	______	______
______	______	______
______	______	______
______	______	______

9. How many days did you fish for *all* types of fish in 1953? (Include striped bass fishing as well as all others.)

   ______________ days.

   If you would like to receive a summary of the report on this survey when it is completed, please check here ☐.

COMMENTS:

FORM 3
The Letter Sent to Those Not Responding to the Original Request

We have not yet received the questionnaire we sent you several weeks ago. Perhaps you did not realize how badly the information was needed in connection with our efforts to maintain and improve angling in California.

You are one of only a few hundred anglers who were included in this state-wide survey. Whether you fished a little or a lot, your record will represent an extremely important part of the over-all picture. Will you please provide us with this record by filling in the questionnaire and returning it to us.

Another questionnaire is enclosed just in case the first one did not reach you or has been misplaced.

Thank you for your cooperation.

Sincerely yours,

SETH GORDON, Director

CALIFORNIA STATE-WIDE ANGLING ESTIMATES FOR 1953[1]

JOHN E. SKINNER
Inland Fisheries Branch
California Department of Fish and Game

Periodic angling surveys are utilized in California as a tool in fisheries management. They are the best source of general information about trends in the sport fish catch and angling pressure in the inland waters of the State. Furthermore, they enable fisheries managers to keep abreast of changes in the major game fish populations. This is particularly important in view of the continual increase in California anglers.

A sample of about 3,000 respondents is necessary to establish valid estimates of numbers of anglers and catches for individual sport fisheries. Since only about a third of the recipients of postal card questionnaires usually respond, it is necessary to triple the sample desired. On that basis an eight-tenths of one percent random sample of all 1953 licensees was mailed questionnaires.[2] In all, 9,323 were mailed, of which 3,127 (33.5 percent) were returned by respondents. Nonresident anglers, who comprise only about 1 percent of the licensees, are included in the survey.

In converting postal card reports into state-wide estimates it is assumed that they are representative of the true population of California anglers. Under this assumption the state-wide estimates are merely the projection of postal card reports by the ratio $\frac{\text{total anglers in State}}{\text{postal card reports}}$.

[1] Submitted for publication September, 1954.
[2] The tenth license stub in every fifth book of 25 was selected.

TABLE 1

Sampling Characteristics of the 1953 Postal Card Survey

	Number	Percentage
Angling licenses sold	1,187,367	----
Questionnaires mailed	9,323	----
Questionnaires returned	3,127	33.5
Respondents who did not fish	126	4.0
Non-usable returns	8	0.3
Unsuccessful respondents	476	15.2
Successful respondents	2,517	80.5
Projection factor (1,187,367 ÷ 3,127)	379.7	----
Average number of fishing days per licensee	14	----

TABLE 2

California State-wide Angling Estimates for 1953

	Trout	Striped bass	Ocean salmon	River salmon	Steelhead	Black bass	Catfish	Crappie	Sunfish
Postal card reports	1,400	137	167	122	147	425	592	353	351
Successful anglers	530,000	166,000	63,100	46,300	56,000	161,000	225,000	134,000	133,000
Standard error	10,600	7,400	1,800	4,100	4,500	7,300	8,300	6,700	6,700
Percent of all licensees	43.8	14.0	5.3	3.9	4.7	13.6	18.9	11.3	11.2
Mean annual catch	42	10	7	5	6	14	33	27	46
Standard deviation	80.2	15.9	10.5	5.7	7.1	21.0	84.0	64.8	59.8
Standard error	2.1	0.8	0.8	0.5	0.6	1.0	3.5	3.5	3.2
Median annual catch	22	6	1	4	4	9	15	12	25
Total annual catch	22,300,000	1,590,000	430,000	210,000	310,000	2,300,000	7,500,000	3,570,000	6,200,000
Standard error	1,500,000	145,000	60,000	30,000	30,000	175,000	820,000	500,000	530,000

In this report the number of licensees represents the total anglers.[3] The sampling characteristics of the 1953 survey are shown in Table 1, while the survey estimates are summarized in Table 2, and subsequently discussed for the various species and also by administrative regions.

Angler and catch estimates are given in terms of successful anglers rather than total anglers fishing for a given species, to permit comparisons with previous surveys. It should be emphasized that the figures derived from these surveys are only approximations, the methods, validity and reliability of which have been discussed in a previous report (Calhoun, 1950).

1953 CATCH ESTIMATES

In this discussion closely related species are grouped together; thus, catfish and bullhead are classified as catfish. Similarly, no distinction is made between the seven species of trout, three species of black bass, two species of crappie, and six species of pan fish.

Trout

An estimated 530,000 anglers or 44 percent of all licensees caught a record total of 22,300,000 trout, as shown in Table 3. This is a 24 percent increase in anglers and a 20 percent increase in trout over the 1951 survey.

TABLE 3
Trends in California Trout Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percentage of angling licensees	Mean	Median
1936	12,000,000	149,000	50	80	50
1937	11,900,000	151,000	48	78	50
1938	12,900,000	160,000	46	79	50
1939	12,800,000	179,000	49	71	37
1941	15,700,000	238,000	53	66	40
1942	16,400,000	234,000	54	70	42
1943	15,700,000	213,000	48	75	37
1946	17,660,000	357,000	47	49	25
1948	18,400,000	415,000	43	44	20
1949	16,700,000	431,000	43	39	--
1951	18,600,000	429,000	42	43	20
1953	22,300,000	530,000	44	42	22

These increases are statistically significant and require some explanation. The greater catch reflects the heavy additional pressure on this fishery (100,000 more anglers than in 1951) and the effects of a greatly expanded catchable trout program. About 5,000,000 "catchables" were planted in 1953, improving fishing in roadside waters throughout the State. This same program is also believed to be partially responsible for the increased angling pressure.

The mean annual catch per successful angler was 42 trout, compared with 43 in 1951. However, the median annual catch, more descriptive of the average angler success, was 22, compared with 20 in 1951.

[3] Actually, the estimates exclude anglers under 16 years of age, who are not required to purchase a license.

Striped Bass

The survey indicates that 1,590,000 striped bass were taken in 1953 by 166,000 anglers. This fishery has remained relatively static in recent years, as depicted in Table 4. The mean catch of 10 "stripers" remained unchanged, but the median rose to six fish for the first time since 1946. This fishery experienced only a 15 percent increase in successful anglers, the lowest of any in the survey.

TABLE 4

Trends in California Striped Bass Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percentage of angling licensees	Mean	Median
1936	2,110,000	84,400	28	25	--
1937	2,040,000	81,900	26	25	--
1938	1,940,000	92,800	27	21	--
1939	1,880,000	89,300	24	21	12
1941	1,940,000	106,000	23	18	10
1942	1,680,000	88,200	20	19	--
1943	1,680,000	75,000	17	22	9
1944	1,420,000	----	--	--	--
1946	1,380,000	113,000	15	12	6
1948	1,650,000	161,000	17	10	5
1949	1,750,000	165,000	17	11	5
1951	1,490,000	144,000	14	10	5
1953	1,590,000	166,000	14	10	6

Salmon and Steelhead

An estimated 640,000 salmon were caught by 110,000 anglers. The popularity of the salmon sport fishery is continuing to grow, as evidenced by the 39 percent increase in anglers over 1951. The mean catch was six, compared with seven in the previous survey. The median catch was four fish instead of three, indicating that the fish were more equitably distributed. Of the total catch, an estimated 430,000 salmon were taken in the ocean and 210,000 in rivers.

Information on steelhead trout was obtained separately for the first time in 1953. About 310,000 of these fish were caught by 56,000 anglers. The mean catch was six and the median four fish. Further details on salmon and steelhead are given in Tables 5 and 6.

TABLE 5

Trends in California Salmon Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percentage of angling licensees	Mean	Median
1936	196,000	25,000	8	8	--
1937	160,000	20,000	6	8	--
1938	178,000	22,000	6	8	--
1939	215,000	31,000	8	7	--
1941	253,000	38,000	8	7	--
1942	180,000	32,000	7	6	--
1943	274,000	31,000	7	9	--
1946	291,000	50,000	7	6	--
1948	321,000	65,000	7	5	2
1949	298,000	67,000	7	4	2
1951	564,000	79,000	8	7	3
1953	640,000	110,000	9	6	4

TABLE 6

Summary of 1953 Salmon and Steelhead Angling

	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percentage of angling licensees	Mean	Median
Ocean salmon	431,000	63,400	5.3	7	4
River salmon	210,000	46,300	3.9	5	4
Steelhead	310,000	55,800	4.7	6	4

Black Bass

The catch of these species in 1953 showed an 81 percent increase over 1951, establishing a new record of 2,300,000. This great increase is attributable to the 49 percent increase in the number of successful anglers, together with improved water conditions in Southern California. Anglers for black bass increased from 108,000 in 1951 to 161,000 in 1953, as shown in Table 7. The status of this fishery appears to be greatly improved, judging by the large rise in both mean and median catches.

TABLE 7
Trends in California Black Bass Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percentage of angling licensees	Mean	Median
1936	930,000	34,000	11	27	--
1937	849,000	33,000	11	26	--
1938	1,190,000	46,000	13	26	--
1939	1,340,000	67,000	18	20	--
1941	1,530,000	75,000	17	20	--
1942	1,340,000	66,000	15	20	--
1943	1,570,000	79,000	18	20	--
1946	1,700,000	104,000	14	16	--
1948	1,890,000	128,000	13	15	6
1949	1,160,000	116,000	12	10	5
1951	1,280,000	108,000	11	12	6
1953	2,300,000	161,000	14	14	9

Catfish

The catfish catch was 59 percent greater than in 1951, 7,500,000 being reported by 225,000 anglers for a 32 percent increase in anglers for these fish. The mean catch jumped from 28 to 33. This is the highest reported number of catfish since 1942, as may be seen from Table 8.

These figures are misleading except for the total catch, because many of the catfish are taken incidentally in striped bass angling. Both species are prominent in the same area, and this factor distorts the actual relationship between catch and angling effort, especially on the basis of days fished for each species.

Regions II and III accounted for more than one-half of the State's total, with most of the catfish coming from the Sacramento-San Joaquin Delta. The elimination of the commercial fishery for catfish may have contributed to the upswing in sport fishing.

TABLE 8
Trends in California Catfish Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percentage of angling licensees	Mean	Median
1936	2,940,000	38,000	13	78	--
1937	2,810,000	43,000	14	65	--
1938	3,480,000	48,000	14	72	--
1939	4,330,000	75,000	20	58	--
1941	6,100,000	97,000	21	63	--
1942	8,250,000	110,000	25	75	--
1943	7,060,000	101,000	23	70	--
1946	6,530,000	149,000	19	44	--
1948	5,560,000	182,000	19	31	15
1949	3,930,000	161,000	16	24	12
1951	4,710,000	171,000	17	29	12
1953	7,500,000	225,000	19	33	15

Crappie

This fishery showed the heaviest increase in anglers (76 percent) over 1951; 134,000 crappie fishermen reported a record catch of 3,560,000.

As indicated in Table 9, the mean catch declined from 31 to 27 over the two-year period, whereas the median remained at 12 fish. The heavy increase in angling pressure is believed to be primarily responsible for the 50 percent increase in the catch.

TABLE 9

Trends in California Crappie Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percentage of angling licensees	Mean	Median
1939	1,720,000	52,000	14	33	--
1941	2,180,000	70,000	15	31	--
1942	2,620,000	66,000	15	40	--
1943	2,670,000	76,000	17	35	--
1946	3,040,000	106,000	14	29	--
1948	2,760,000	116,000	12	24	12
1949	2,430,000	105,000	11	23	10
1951	2,380,000	76,000	7	31	12
1953	3,570,000	134,000	11	27	12

Sunfish

Sunfish angling followed the general trend of other fisheries, since a record total of 6,200,000 sunfish was reported, for a 29 percent increase. Table 10 shows that an estimated 133,000 anglers caught sunfish.

TABLE 10

Trends in California Sunfish Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percentage of angling licensees	Mean	Median
1939	2,090,000	51,000	14	41	--
1941	2,770,000	63,000	11	44	--
1942	3,060,000	57,000	13	54	--
1943	3,040,000	68,000	15	45	--
1946	4,320,000	122,000	16	35	--
1948	4,820,000	118,000	12	41	20
1949	4,020,000	114,000	11	35	20
1951	4,800,000	102,000	10	47	20
1953	6,200,000	133,000	11	46	25

DISCUSSION

As the foregoing statistics show, there was an obvious departure from the 1951 survey in that most species showed a heavy increase in both the total catch estimates and the number of anglers fishing for each species, especially some of the warmwater fishes. The increase is not especially significant, however, when it is realized that the 1951 survey followed a prolonged drought in Southern California, which had

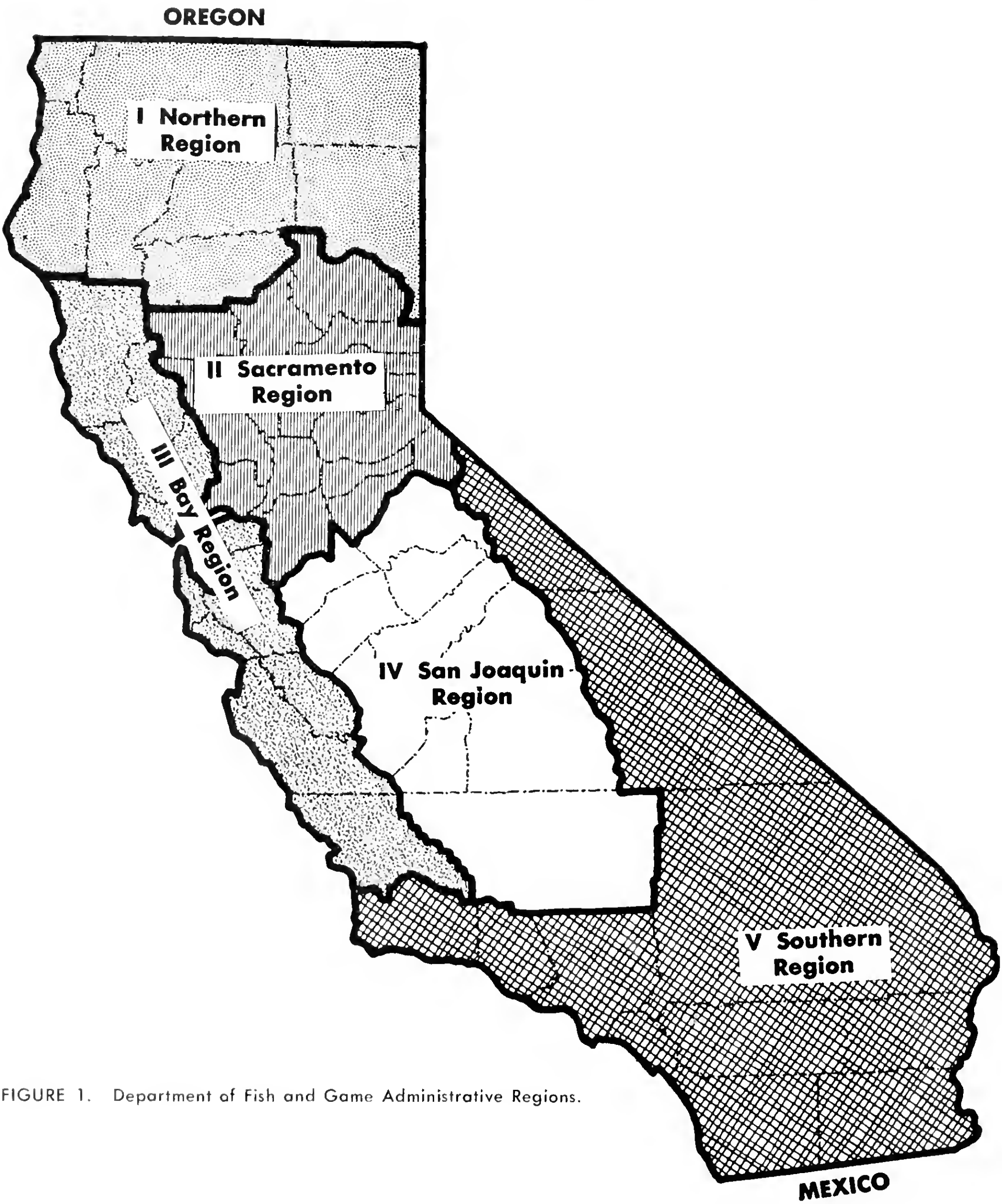

FIGURE 1. Department of Fish and Game Administrative Regions.

serious adverse effects upon the warmwater fisheries there. The present high survey estimates appear to be the result of a combination of factors, of which improved water conditions seem to be the foremost. In view of the relatively poor ocean sport fishing in 1953, it is highly probable that many of these enthusiasts turned to freshwater fishing. The unprecedented increase in anglers, especially in Southern California, seems to verify this and has obviously influenced the catch.

CATCH ESTIMATES BY ADMINISTRATIVE REGIONS

The catch estimates have been tabulated for the five administrative regions shown in Figure 1, based on those respondents who reported the county of catch. Unsuccessful anglers are included in the regional catch estimates and the regional mean annual catches are therefore lower than the state-wide mean.

The combined regional catch estimates for any single species do not equal the state-wide total because some anglers do not report the county of catch. The combined regional angler estimates, however, are greater than the state-wide total for any one species because many anglers fished in several regions.

Region I (Northern California)

This region covers the northern portion of California and extends the entire width of the State, as shown in Figure 1. The area provided about 36 percent of the salmon catch, a little more than half of which was taken in the coastal rivers and streams. Region I also contributed about 18 percent of the trout and 76 percent of the steelhead catch. Other species are of negligible importance in this region, as indicated in Table 11. About 49,000 or 4 percent of the anglers live here.

TABLE 11

Angling in Region I

Species	Number of reports	Regional catch		Anglers		Regional mean annual catch
		Total	Percentage of state catch	Total	Percentage of state total	
Trout	258	3,700,000	17.8	136,000	13.8	27
Ocean salmon	36	106,000	25.5	14,000	22.8	8
River salmon	56	115,000	56.9	21,000	40.3	5
Steelhead	85	200,000	75.8	32,000	47.8	6
Black bass	31	120,000	5.7	12,000	6.1	10
Catfish	12	165,000	2.7	5,000	1.9	33
Crappie	8	140,000	4.2	3,000	2.1	47
Sunfish	8	225,000	3.9	3,000	2.2	75

Region II (Sacramento Region)

Region II is comprised of the northern Sierra Nevada, the Sacramento Valley, and the Sacramento-San Joaquin Delta. The fisheries of this region are highly diversified, as illustrated in Table 12. Approx-

imately 45 percent of the striped bass and 50 percent of the catfish were taken in Region II. It also provided 11 percent of the salmon, almost all of which came from the Sacramento River drainage. An estimated 14 percent or 161,000 anglers live in Region II.

TABLE 12

Angling in Region II

Species	Number of reports	Regional catch		Anglers		Regional mean annual catch
		Total	Percentage of state catch	Total	Percentage of state total	
Trout	378	5,100,000	24.4	144,000	20.3	35
Striped bass	257	600,000	44.5	98,000	49.2	6
River salmon	50	68,000	33.7	19,000	36.0	4
Steelhead	31	27,000	10.2	12,000	17.4	2
Black bass	97	310,000	14.0	37,000	19.0	8
Catfish	240	3,100,000	49.7	91,000	38.6	34
Crappie	33	290,000	8.7	13,000	8.5	22
Sunfish	54	790,000	13.8	21,000	14.5	38

Region III (Bay Region)

The Bay Region extends along the central coastal portion of the State from Mendocino to San Luis Obispo counties, inclusive. Although the sport fisheries here are also diverse, the principal ones are for striped bass and salmon. More than one-half of the total catches of these species were taken in Region III. The stripers are caught in the lower Delta and in the San Francisco Bay area, while the salmon are taken primarily in the ocean off the Golden Gate.

This area also contributed one-quarter of the total black bass and sunfish catch, much of which came from Clear Lake, Lake County. Although the trout catch was the lowest of any region, almost 2,000,000 were caught. Crappie and catfish caught here represented about one-seventh of the total catch of these species, as shown in Table 13. An estimated 323,000 or 27 percent of the anglers reside here.

TABLE 13

Angling in Region III

Species	Number of reports	Regional catch		Anglers		Regional mean annual catch
		Total	Percentage of state catch	Total	Percentage of state total	
Trout	174	1,840,000	8.8	66,000	9.3	28
Striped bass	254	730,000	54.5	96,000	48.7	8
Ocean salmon	122	310,000	71.5	46,000	77.2	7
River salmon	24	15,000	7.4	9,000	17.3	2
Steelhead	58	34,000	12.9	22,000	32.6	2
Black bass	110	540,000	24.6	42,000	21.6	13
Catfish	101	920,000	14.9	38,000	16.2	24
Crappie	62	440,000	13.2	24,000	16.1	18
Sunfish	83	1,370,000	23.9	32,000	22.3	43

Region IV (San Joaquin Region)

This region includes the San Joaquin Valley and the southern Sierra Nevada. About 3,250,000 trout were taken in the region, for 15 percent of the state total. About 15 percent of the black bass were also caught here in 1953, and about one-tenth of the catfish, sunfish, and crappie. As indicated in Table 14, other fisheries were negligible.

Region IV is the residence of 129,200 anglers, or 11 percent of the total.

TABLE 14

Angling in Region IV

Species	Number of reports	Regional catch		Anglers		Regional mean annual catch
		Total	Percentage of state catch	Total	Percentage of state total	
Trout	353	3,270,000	15.7	134,000	18.9	24
Striped bass	11	13,000	1.0	4,000	2.1	3
River salmon	9	4,000	2.0	3,000	6.4	1
Steelhead	3	2,000	0.7	1,000	1.7	2
Black bass	80	350,000	15.7	30,000	15.7	12
Catfish	89	790,000	12.8	34,000	14.3	23
Crappie	46	310,000	9.4	18,000	11.9	17
Sunfish	59	690,000	12.1	22,000	15.9	31

Region V (Southern Region)

The Southern Region is the largest of the administrative regions and covers all counties south of San Luis Obispo and Kern counties and also includes Mono and Inyo counties on the east slope of the Sierra Nevada. The latter counties are almost exclusively trout areas, and accordingly the trout data have been kept separately for them.

Mono and Inyo counties, combined with San Bernardino County, produced about 5,600,000 trout, or 81 percent of the regional catch and 27 of the state total. Mono and Inyo counties alone contributed 4,550,000 trout. The total regional catch was 6,950,000 trout or 33 percent of the state total, as shown in Tables 15 and 16.

TABLE 15

Angling in Region V

Species	Number of reports	Regional catch		Anglers		Regional mean annual catch
		Total	Percentage of state catch	Total	Percentage of state total	
Trout	707	6,950,000	33.4	268,000	37.8	26
Black bass	192	880,000	40.0	73,000	37.6	12
Catfish	180	1,230,000	19.9	68,000	28.9	18
Crappie	237	2,140,000	64.4	90,000	61.4	24
Sunfish	168	2,660,000	46.4	61,000	45.2	42

TABLE 16

Trout Angling in Southern California and in Mono-Inyo Counties

Area	Number of reports	Regional catch		Anglers		Regional mean annual catch
		Total	Percentage of state catch	Total	Percentage of state total	
Mono-Inyo	364	4,550,000	21.8	138,000	19.5	33
Southern California	343	2,400,000	11.5	130,000	18.3	18

The mean annual catch in the Mono-Inyo area was almost twice that of the rest of Region V, with approximately the same number of anglers fishing in both portions.

This region has the most important warmwater fishery in the State, yielding 40 percent of the black bass, 64 percent of the crappie, and 46 percent of the sunfish. An estimated 509,600, or 43 percent, of the State's anglers live in Region V.

FISHING SUCCESS AND INTENSITY

Table 17 presents data on the catches of successful anglers who reported the number of days they fished for various species.

TABLE 17

Mean Annual and Daily Catch Estimates for Successful Anglers

Species	Number of reports	Mean catch per angler year	Mean days per angler	Mean catch per angler day
Trout	1,277	42.5	8.4	5.1
Striped bass	379	9.8	10.1	1.0
Ocean salmon	145	6.8	4.5	1.5
River salmon	89	4.4	6.0	0.7
Steelhead	120	5.7	6.2	0.9
Black bass	331	13.1	5.3	2.5
Catfish	158	29.8	7.1	4.2
Crappie	274	23.0	4.5	5.1
Sunfish	258	45.1	5.4	8.4

Anglers spent an estimated 15,500,000 days fishing in California in 1953, one-third of them for trout. Ocean fishing accounted for 22 percent of the total days, fishing for warmwater species accounted for 24 percent, and fishing for striped bass 13 percent. Further details are given in Table 18. The average angler spent 14 days in pursuit of his sport during the year.

TABLE 18

Number of Days Fished by California Anglers in 1953

Species	Number of reports	Angling days	Standard error	Percentage of total days	Mean days fished	Standard deviation	Standard error of mean	Median days fished
Trout	1,371	4,650,000	93,000	34.10	8	8.1	0.05	5
Striped bass	487	2,000,000	104,000	14.59	10	13.4	0.60	5
Ocean salmon	172	330,000	40,000	2.32	5	6.8	0.52	3
River salmon	127	320,000	40,500	2.27	6	7.5	0.66	1
Steelhead	163	410,000	40,700	3.02	6	7.9	0.62	1
Black bass	387	910,000	52,000	6.03	5	6.0	0.30	3
Catfish	473	1,520,000	105,000	9.89	7	11.0	0.50	4
Crappie	281	600,000	43,000	3.76	5	5.6	0.33	3
Sunfish	269	670,000	34,000	4.29	5	5.1	0.10	3
Ocean fishing*	823	3,100,000	----------	22.06	8	12.9	0.45	4

* Includes ocean salmon.

SUMMARY

A state-wide survey was made to evaluate angling in California during 1953. Eight-tenths of 1 percent of all licensees were mailed postal card questionnaires. Of the 9,323 cards mailed, 3,127 or 33.5 percent were returned by respondents.

The trout catch in 1953 was significantly greater than in 1951. This is attributed to increased stocking of catchable trout and a large increase in the number of anglers for these species. A total of 22,300,000 trout was caught by 530,000 successful anglers.

California's salmon sport fishery continued to increase, since 110,000 anglers reported catching 640,000 salmon.

Striped bass angling remained virtually unchanged. An estimated 166,000 anglers caught 1,590,000 stripers.

Catches of black bass and catfish showed highly significant increases over the 1951 survey. The increase is attributable to increased angling pressure and improved water conditions, following a prolonged drought, in Southern California. Other warmwater species also showed notable increases in both the total catch estimates and numbers of anglers.

An estimated 15,500,000 days were spent angling in California in 1953, one-third of them for trout. Ocean fishing accounted for 22 percent of the total.

The estimates indicate a decline in ocean sport fishing and a corresponding increase in freshwater fishing in 1953.

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WATERFOWL HUNTING AREAS OPERATED BY THE CALIFORNIA DEPARTMENT OF FISH AND GAME[1]

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INTRODUCTION

The war industries of World War II were responsible for a mass migration of people into the State of California. This influx has continued to the present time and has resulted in an increased demand for recreational facilities, including places to hunt. At the same time that hunting pressure was increasing, waterfowl habitat was decreasing, as marshlands were drained and converted to agricultural use. Thus, waterfowl hunters were finding fewer places to hunt.

Shortly after World War II the California Department of Fish and Game embarked on a program to furnish the unattached hunter with a place to shoot waterfowl by using a management plan for the State's waterfowl areas. As stated by Gordon (1950), this plan for the management of California's waterfowl areas (both state and federal) accomplishes a threefold purpose:

1. To provide for the needs of waterfowl by supplying suitable habitat upon which they can exist.
2. To provide living space with adequate food of suitable quantity and quality to keep the birds from raiding agricultural crops during the critical period of crop development and the harvest.
3. To provide public shooting for as many of the unattached shooters as can be accommodated.

The following is a report on the third point of this plan, and shows the areas involved, hunter use, and hunting success for the period 1948-53.

ACKNOWLEDGMENT

Acknowledgment with appreciation is made to John E. Chattin, now of the U. S. Fish and Wildlife Service, who compiled the waterfowl hunting statistics during the beginning years (1948-50) of the hunting area operations; to all the Department of Fish and Game personnel who worked on the areas, especially the area leaders, John B. Cowan, Nick Ermacoff, Malcolm E. Foster, James Gilman, Don Neilson, Laurence Rubke, Edward R. Schneegas, Merl Sturgeon, and Roy M. Wattenbarger; to Gene Crawford, Vernon Ekedahl, and Edward O'Neill of the U. S. Fish and Wildlife Service areas; to U. S. Bureau of Reclamation personnel; and to Cliffa Corson, who prepared the maps.

[1] Submitted for publication September, 1954. Federal Aid in Wildlife Restoration Act Project, California, W-30-R, "A Study of Waterfowl in California."

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DESCRIPTION OF AREAS

In 1948 only three waterfowl areas were involved in the Department's hunting program, but since that time considerable expansion has taken place. In 1950 federal Lea Act lands were added, and in 1952 leased lands were included in the plan. At present 11 areas offer shooting to waterfowl hunters. Since the location of these public hunting grounds (Figure 1) extends over the State from the Mexican

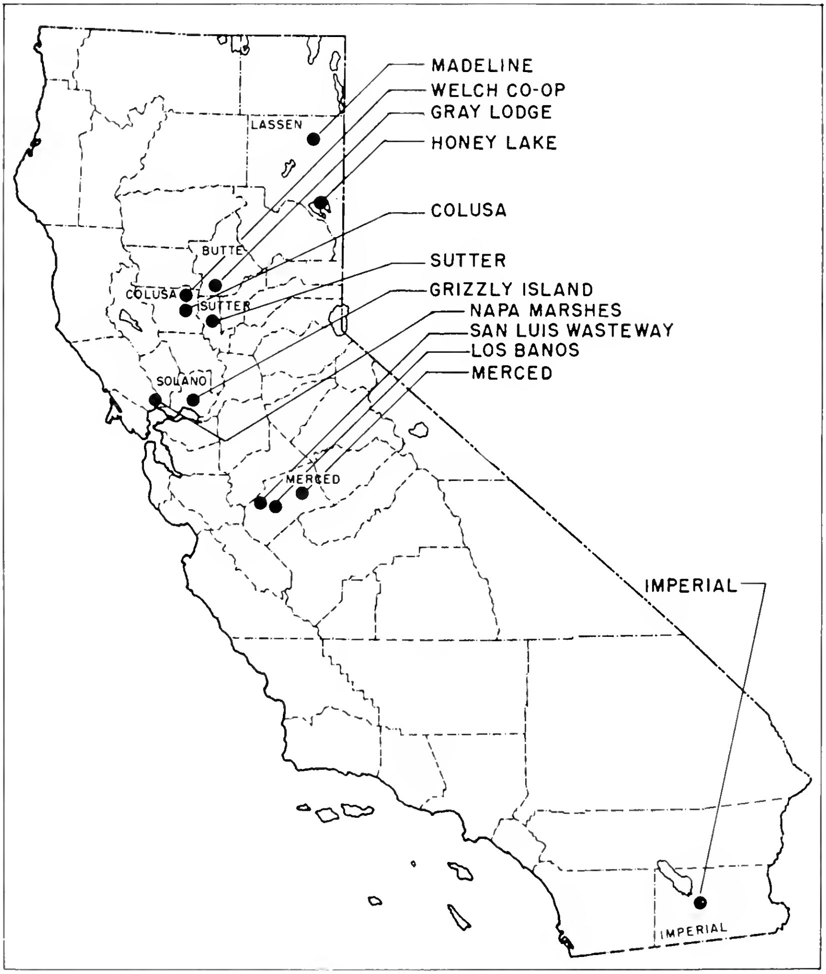

FIGURE 1. Location of the waterfowl hunting areas operated by the California Department of Fish and Game.

border nearly to the Oregon state line, the areas vary greatly in climate and topography. For example, Madeline Plains and Honey Lake, located in northeastern California, lie at an altitude of over 4,000 feet, and are situated in an area with the Great Basin sagebrush

type of vegetation; in contrast, the Imperial area in Southern California lies 230 feet below sea level in what was once arid desert. This region did not become waterfowl habitat until 1905-06, when the Colorado River overflowed into Imperial Valley and created the present Salton Sea. Between these extremes, the Sacramento Valley areas are found just above sea level in what was once ancestral waterfowl wintering grounds but is now the rich agricultural "rice bowl."

The following are brief descriptions of each of the hunting areas.

State Lands

Madeline Plains Waterfowl Management Area is located on U. S. Highway 395 two miles south of the town of Madeline in Lassen County. The area totals 5,176 acres, of which 2,400 acres are open to hunting. When this land was first acquired by the department in 1945-46, it was not considered good waterfowl habitat, but with the development of ponded areas and cultivation of grain crops area managers have succeeded in attracting ever increasing numbers of waterfowl into the area. Consequently, more hunters are now using the area.

Honey Lake Waterfowl Management Area is situated at the northern edge of Honey Lake, Lassen County, and is about 22 miles east of Susanville via U. S. Highway 395. The area is comprised of the Fleming and Dakin units. These two units total 5,500 acres, with 3,000 acres open to hunting. The area is used by waterfowl not only as a feeding and resting area during migration, but also as one of the major nesting areas in the State. A limited amount of hunting has been allowed on this area ever since it was purchased in 1945-46.

Gray Lodge Waterfowl Management Area is located in the Sacramento Valley about 10 miles southwest of Gridley, Butte County. Originally an area of 2,542 acres, it was operated as an inviolate refuge from 1932 through 1952. With additional lands being acquired for an eventual expansion to 6,000 acres, status of the refuge has been changed to a management area. Hunting was first allowed in 1953, when 1,200 acres were opened to shooting. Gray Lodge is used heavily by wintering waterfowl, with over a million ducks being tallied there during winter inventories.

Grizzly Island Waterfowl Management Area is a tract of 8,600 acres, comprising the greater share of Grizzly Island in Suisun Bay, Solano County. The area, which was acquired in 1950 with Wildlife Conservation Board funds, has 5,000 acres open to hunting. Even though the island can be reached only by ferry, it has proved to be our most popular area, since it not only offers good hunting, but also lies close to the large population centers that are clustered around San Francisco Bay. Transportation difficulties will be eased when the ferry is replaced by a bridge.

Los Banos Waterfowl Management Area is located in the San Joaquin Valley approximately four miles northeast of the town of Los Banos, Merced County. This area comprises a small portion of the famous Grasslands waterfowl wintering grounds. Since 1929 it has been a refuge, but in 1953 1,070 acres were opened for hunting.

Imperial Waterfowl Management Area is located at the southerly end of the Salton Sea, Imperial County. The area is made up of several different units. The Hazard and Finney-Ramer units, totaling 2,600 acres, are state-owned. When the Finney-Ramer unit was purchased in 1932 it was known as the Imperial Refuge. It was operated as an inviolate waterfowl refuge until 1944, when it was opened to public hunting. In 1952 development work was started with Wildlife Conservation Board funds to create a multiple-use area that could be used for both hunting and fishing. The Pumice and Poe units are lands leased from the Imperial Irrigation District under an agreement whereby lands below the minus 230-foot contour could be used for waterfowl management purposes. At one time these leased units totaled 3,880 acres, but now most of this land has been inundated by the rising Salton Sea. More land is now being acquired on higher ground. State-controlled hunting is also provided on 1,200 acres of the Salton Sea National Wildlife Refuge, which is known as the Federal unit.

Federal Lands

Under provisions of the Lea Act, certain lands purchased by the U. S. Fish and Wildlife Service may be opened to hunting by the public under control of the California Department of Fish and Game. These are as follows:

Colusa National Wildlife Refuge is located in the Sacramento Valley about five miles southwest of the town of Colusa, Colusa County. An area totaling 4,040 acres, it became the first Lea Act land to be opened to hunting when in 1950 hunting was allowed on 1,090 acres. It is an important waterfowl wintering area.

Sutter National Wildlife Refuge is also located in the Sacramento Valley. It is situated in Sutter County, about 20 air-line miles southeast of Colusa National Wildlife Refuge. This area, too, is important to wintering waterfowl. Hunting was first allowed in 1953, when 1,000 acres were opened.

Merced National Wildlife Refuge is located in the San Joaquin Valley, in Merced County about 15 miles northeast of the Los Banos Waterfowl Management Area. It provides feeding and resting areas for the large populations of waterfowl wintering on the Grasslands. Since 1951 hunting has been allowed on about 1,000 acres of the area.

Leased Lands

The Department of Fish and Game also provides waterfowl hunting on some leased lands, as follows:

San Luis Wasteway is a 1,500-acre tract of land that is leased from the U. S. Bureau of Reclamation. It is located in Merced County about six miles west of the Los Banos Waterfowl Management Area and is used as a wasteway for irrigation water of the Central Valley Project.

Napa Marshes is an area of 5,000 acres of islands, backwaters, and sloughs that was leased in 1953 from the Leslie Salt Company. The area is situated about one mile northwest of Vallejo, connects with San Francisco Bay, and is accessible only by boat.

Welch Cooperative Hunting Area comprises 5,680 acres of agricultural land leased from a private rancher. It is located in the Sacramento Valley four miles east of Maxwell, Colusa County, and is

operated under cooperative hunting area regulations, described by Harper, Metcalfe, and Davis (1950) for pheasant hunting. Some cooperative hunting areas are potential waterfowl hunting sites, but water control on leased lands is not always adequate to assure good waterfowl shooting.

HUNTING PROCEDURE

To prevent excessive concentrations of hunters and to promote safe hunting, each area had assigned to it a maximum number of hunters that could be in the field at any one time. Depending on the physical nature of the area, hunter quotas were determined by allowing from 10 to 15 acres of open shooting land per hunter.

In order to allow as many different individuals as possible to take part in the hunting, priority was given to the first-time hunter on each area. But if the quota was not filled with first-time hunters by one hour before shooting time, repeat hunters were allowed to fill the quota.

FIGURE 2. Hunters lined up at the checking station on the Colusa area. *Photograph by Dave Marshall, U. S. Fish and Wildlife Service.*

Until 1953 no general fee was charged for admittance to the areas. However, on the Imperial, Grizzly Island, and Merced areas a limited number of double blinds were maintained, and the hunters could reserve blinds in advance for a fee of $5 per day for each shooter, if they desired. In 1953, to help defray operating costs, a daily fee of $2 per shooter was charged on all areas except three. On the two northern areas of Honey Lake and Madeline Plains free hunting was still allowed, while at Napa Marshes $3 was charged for a season permit. At the same time the $5 fee for blinds was eliminated on the Grizzly Island and Merced areas. However, advanced reservation for blinds on the Imperial area was continued, to assure hunters from Los Angeles and San Diego of having a place to hunt before undertaking the long drive from the coast.

The days on which the areas were open to hunting were quite similar to the traditional pattern followed by California duck clubs. The shooting days for all the areas, except Napa Marshes, were Wednesdays,

STATE OF CALIFORNIA
DEPARTMENT OF FISH AND GAME

Date DEC 3 0 1953 **STATE-CONTROLLED HUNTING AREA PERMIT**

GENERAL PERMIT № 1658 G

Fee: $2.00

Important—Read Before Signing

1. All hunters must obtain valid permits before hunting on this area and return filled out permits before leaving the area or at the end of the period for which issued.
2. Permits are valid only for dates and area issued.
3. Where identification markers are issued, they must not be removed from the area where issued and must be turned in at the end of the day or period for which the permit is issued.
4. The State reserves the right to refuse to issue a permit to anyone and to revoke any permit and to eject the holder from the area for any reason when it appears that the safety or welfare of the area, or that of other permittees, is endangered. Decision of the authorized employee of the Department of Fish and Game in this respect shall be final.
5. Permits will be issued only to holders of valid hunting licenses. Deer tags, pheasant tags, or Federal Migratory Waterfowl stamps are required where applicable.
6. Any unauthorized person who enters upon a state-controlled hunting area shall be deemed a trespasser.
7. Only the species and sex of game designated by the permit may be taken.
8. Any portion of this state-controlled hunting area may be closed or restricted by the Department of Fish and Game by legally posting notice of the same.
9. Use of this area shall be at the sole risk of the permittee, and neither the Department of Fish and Game nor the landowner shall be liable in damages to any permittee.
10. The Rules and Regulations for the operation of this area are posted in all checking stations and are incorporated in and made a part of this permit as though set out in full herein.

I, the undersigned, acknowledge that I have read all the rules and regulations pertaining to this permit, some of which are set forth hereinabove, and agree to be bound by the same. By signing my name hereto, I specifically waive for myself, my heirs, administrators, assigns and assignees, all claim and demand against the State of California, its officers, agents, servants, or employees, or the owner or owners of any land contained in this area, for all injury or loss accruing or arising in any manner whatsoever while I am exercising the privileges granted by this permit, using the area, or while en route to or from the same.

Signature of Permittee John E. Drake

Address 240 Marsh Ave, Duck City
(Street and Number) (City)

STATE OF CALIFORNIA
DEPARTMENT OF FISH AND GAME

Date DEC 3 0 1953 **HUNTER PERMIT** № 1658 G

GENERAL PERMIT

Fee: $2.00

State-Controlled Hunting Area

The bearer is hereby granted permission to hunt on this hunting area in accordance with rules and regulations of the Fish and Game Commission.

This permit is valid only on date or dates and area for which issued and is not transferable.

Use of this area is at the sole risk of the permittee, and neither the Fish and Game Commission nor the landowner shall be liable in damages to any permittee.

Coot KILL RECORD Validated CRT

	MALE	FEMALE		MALE	FEMALE		
Mallard	1		Shoveller			Canada Goose	
Gadwall			Ruddy			Cackling Goose	
Baldpate		1				White Front	1
Pintail	2					Lesser Snow	
G W Teal	2	1	TOTAL DUCKS	5	2	TOTAL GEESE	1

FIGURE 3. Application and permit form used on the waterfowl hunting areas.

Saturdays, Sundays, the opening and closing dates of each legal waterfowl hunting season, and the holidays of Armistice Day, Thanksgiving Day, and Election Day when they fell within the waterfowl season.

Checking stations were operated on each area to issue permits, collect fees, maintain hunter quotas, dispense information, and check the returning hunters' waterfowl kill. At the checking station, each hunter filled out the top half of the permit form by recording his address and signing a waiver for any claim of loss or damage against the State. The bottom half of the perforated form, the actual permit, was given to the hunter, while the top half with the waiver, name, and address was retained at the checking station (Figure 3.) The hunter then paid his fee and had his hunting license punched with a distinguishing mark to indicate that he had hunted on the area as a first-time hunter. When he had completed his hunt, he checked back out and returned his permit.

The hunting procedure on Napa Marshes was entirely different from that of the other areas. Because of the numerous points of access by water, it was not deemed feasible to check all hunters in and out of the area. Instead, seasonal permits were issued, no hunter quotas were established, and hunting was allowed every day of the waterfowl season. Department personnel patrolled the area by boat, checking for violations and trespassers, and recording hunting success.

Detailed regulations covering the hunting procedures described above are adopted each year by the California Fish and Game Commission. By acting on these regulations annually, necessary changes can be made as conditions warrant. A copy of the 1953 regulations is presented in the Appendix.

HUNTING SEASON RESULTS

As each hunter left the area, he returned his permit to the checking station attendant, who recorded the hunter's waterfowl kill upon it. The hunting season statistics were then compiled from the information recorded on the permits. Table 1 summarizes the hunting activities for the number of years that each area has been in operation. The third column shows the scheduled capacity of hunters for each season and is derived by multiplying the daily quota by the number of shoot days.

It will be noted (fourth column) that many areas actually accomodated more hunters than their scheduled capacity. This situation is explained by the fact that on the more popular areas as hunters completed their shooting and left the area other hunters replaced them to refill the quota. After 2 p.m. no new hunters were admitted to the areas.

All of the areas do not have an equal number of shooting days during each hunting season. In the north, Madeline Plains may freeze over and put an end to hunting before the waterfowl season officially closes. The hunting areas in the Central Valley, such as Gray Lodge and Merced, have delayed openings for protection of agricultural crops on the

TABLE 1

California Waterfowl Public Hunting Area Operations From 1948 Through 1953

Area	Acreage open to hunting	Scheduled seasonal shooting capacity*	Actual number of hunters using area	Number of waterfowl shot	Average number waterfowl per hunter	Number of shoot days	Duck bag limit
Madeline							
1948	2,400	4,080	93	37	0.4	17 days	5 ducks
1949	2,400	4,800	75	161	2.2	20 days	5 ducks
1950	2,400	1,200	16	6	0.3	5 days	6 ducks
1951	2,400	4,560	111	144	1.3	19 days	6 ducks
1952	2,400	6,720	473	897	1.9	28 days	6 plus 2
1953	2,400	6,960	1,064	1,655	1.6	29 days	7 plus 4
Honey Lake							
1948	1,750	1,700	586	425	0.7	17 days	5 ducks
1949	1,750	2,000	558	518	0.9	20 days	5 ducks
1950	1,000	1,250	1,003	1,029	1.0	25 days	6 ducks
1951	3,000	3,400	3,611	3,881	1.1	34 days	6 ducks
1952	3,000	5,250	3,677	3,756	1.0	39 days	6 plus 2
1953	2,500	4,800	2,912	2,196	0.8	32 days	7 plus 4
Imperial							
1948	3,580	9,720	1,358	2,078	1.5	17 days	5 ducks
1949	3,580	11,440	2,201	4,510	2.1	20 days	5 ducks
1950	3,904	16,500	2,523	4,331	1.7	25 days	6 ducks
1951	4,339	21,780	5,285	11,802	2.2	30 days	6 ducks
1952	3,525	22,200	5,904	14,586	2.5	35 days	6 plus 2
1953	2,325	9,900	4,801	10,475	2.2	32 days	7 plus 4
Grizzly Island							
1950	3,897	7,500	4,564	4,897	1.1	25 days	6 ducks
1951	4,000	8,700	9,646	17,723	1.8	30 days	6 ducks
1952	4,500	14,000	16,047	44,126	2.8	35 days	6 plus 2
1953	5,000	15,200	11,936	41,218	3.5	32 days	7 plus 4

Colusa							
1950	1,090	1,325	1,647	2,435	1.5	25 days	6 ducks
1951	1,000	1,725	2,398	3,591	1.5	23 days	6 ducks
1952	1,100	2,160	3,350	6,832	2.0	27 days	6 plus 2
1953	1,100	1,760	2,566	7,786	3.0	22 days	7 plus 4
Merced							
1951	1,200	1,920	729	860	1.2	25 days	6 ducks
1952	1,200	2,400	1,180	1,717	1.5	30 days	6 plus 2
1953	1,000	1,920	1,194	2,255	1.9	24 days	7 plus 4
San Luis Wasteway							
1952	1,500	3,500	3,740	6,881	1.8	35 days	6 plus 2
1953	1,500	3,200	3,579	8,314	2.3	32 days	7 plus 4
Gray Lodge							
1953	1,200	1,760	2,113	8,549	4.0	22 days	7 plus 4
Sutter							
1953	1,000	1,650	2,386	9,561	4.0	22 days	7 plus 4
Los Banos							
1953	1,070	2,400	1,736	3,070	1.8	24 days	7 plus 4
Welch Co-op							
1953	5,680	8,800	3,047	3,122	1.0	32 days	7 plus 4
Totals:							
1948	7,730	15,500	2,037	2,540	1.2		
1949	7,730	18,240	2,834	5,189	1.8		
1950	12,291	27,775	9,753	12,698	1.3		
1951	15,939	42,085	21,780	38,001	1.7		
1952	17,225	56,230	34,371	78,795	2.3		
1953	24,775	58,350	37,334	98,201	2.6		

* Daily quota of shooters multiplied by the number of shoot days.

surrounding lands. Every effort is made to encourage the birds to remain on the waterfowl management area until adjoining crops are harvested.

It will be noted that hunting success on the areas has increased progressively over the six-year period. Probably most of the increase since 1948 has been due to the larger populations of waterfowl and the subsequent relaxation of the hunting regulations. Table 1 shows that the liberalized regulations of 1953, which included a basic limit of seven ducks plus an additional four pintails and or widgeon, coincide with the highest hunting success that has been recorded. That year the Sutter and Gray Lodge areas, in their first year of operation, averaged four birds per hunter, the highest average ever recorded for any of the areas for a complete season. As any duck hunter knows, hunting success for any one day will vary with weather conditions and the movements of the birds. All of the areas have had hunting days with shooting so excellent that good hunters had no trouble taking a limit of ducks. For instance, on October 16, 1953 at Grizzly Island 413 hunters took 2,893 ducks for an average of seven ducks (the basic limit) per hunter. On November 7, 1953 on the Colusa area 131 hunters shot 818 ducks for an average kill of 6.2 ducks per hunter. One of the best days on the Sutter area was December 27, 1953, when 161 hunters killed 1,010 ducks for an average bag of 6.3 ducks per hunter. Naturally, there are times when hunting success can be just the opposite of that cited above, with the records showing more hunters present than ducks killed.

Since checking stations were not operated at Napa Marshes, any hunting season statistics collected there would not be comparable to the data from the other areas. Therefore, results of the hunting operations at Napa Marshes were not included in Table 1. However, in order to determine hunter use and hunting success on that area, a questionnaire was mailed to 10 percent of the 1,650 holders of season permits. This survey indicated that 2,780 hunter days were spent on the area, and that 7,150 ducks, 50 geese, and 690 coots were shot. The average number of birds was 2.8 per hunter, which compares favorably with the 2.6 average obtained on the other hunting areas.

Tables 2 through 5 show the species composition of the kill for the four years, 1950-53. Pintail predominated in the total duck kill, especially in the years 1952 and 1953, when the pintail population was high and the bag limit for this species was liberalized. Although the pintail was most prevalent in the total kill and is the most common duck in California, it did not predominate on all areas. On most areas, the kill reflects to some degree the composition of the local duck population. From the actual populations, one would expect the mallard to be the duck most numerous in the kill at Madeline Plains and Honey Lake and it should also rank high around the Butte Sink and Colusa Trough. This supposition is supported by the kill at the Gray Lodge, Colusa, Welch Co-op, and Suter areas. On the other hand, even though green-winged teal and shovellers are fairly common in the San Joaquin Valley and Imperial Valley, they rank higher in the kill than they do in the actual population.

TABLE 2

Species Composition of Waterfowl Killed on California Public Shooting Areas—1950

Species	Madeline Plains	Honey Lake	Colusa	Grizzly Island	Imperial	Totals	Percentage of kill
Mallard (*Anas platyrhynchos*)	3	299	386	650	15	1,353	11.5
Gadwall (*Anas strepera*)	--	55	7	24	18	104	0.9
Baldpate (*Anas americana*)		82	518	590	658	1,848	15.7
Pintail (*Anas acuta*)	--	185	491	2,168	1,188	4,032	34.3
Green-winged Teal (*Anas carolinensis*)	--	86	394	578	1,029	2,087	17.7
Cinnamon Teal (*Anas cyanoptera*)	1	1	28	12	112	154	1.3
Shoveller (*Spatula clypeata*)		45	130	530	669	1,374	11.7
Redhead (*Athya americana*)		26	1	14	69	110	0.9
Canvasback (*Athya valisineria*)		2	5	5	9	21	0.2
Ring-necked Duck (*Athya collaris*)		--	6	2	2	10	0.1
Lesser Scaup (*Athya affinis*)		22	16	7	116	161	1.4
American Goldeneye (*Bucephala clangula americana*)		8	-----	12	8	28	0.2
Bufflehead (*Bucephala albeola*)		8	7	9	18	42	0.3
Ruddy Duck (*Oxyura jamaicensis rubida*)		40		68	295	403	3.4
Fulvous Tree Duck (*Dendrocygna bicolor helva*)				--	41	41	0.3
Others and unclassified		2		2	3	7	0.1
Subtotal—ducks	4	861	1,989	4,671	4,250	11,775	100.0
Canada Goose (*Branta canadensis*)		75	12	----	7	94	16.7
White-Fronted Goose (*Anser albifrons*)	--	5	86	37	3	131	23.3
Cackling Goose (*Branta canadensis minima*)	2	37	192	14	----	245	43.5
Lesser Snow Goose (*Chen hyperborea hyperborea*)	--	43	43	3	4	93	16.5
Subtotal—geese	2	160	333	54	14	563	100.0
Coot (*Fulica americana*)	0	8	113	172	67	360	-------
Total waterfowl	6	1,029	2,435	4,897	4,331	12,698	--------

Since most of the diving ducks confine themselves to coastal areas, they are not very common on the hunting areas. However, the duck kill that was sampled at Napa Marshes showed that the canvasback was the duck most frequently taken by hunters.

Table 6 shows the county of residence for each hunter using the waterfowl hunting areas in 1953. The bold-faced figure in each column shows the number of hunters from the county in which the area lies. The majority of the hunters using the northern areas of Madeline Plains and Honey Lake were local residents. The reason for this preponderance of local hunters is that there is a scarcity of places to hunt

TABLE 3

Species Composition of Waterfowl Killed on California Public Shooting Areas—1951

Species	Madeline Plains	Honey Lake	Colusa	Grizzly Island	Merced	Imperial	Totals	Percentage of kill
Mallard	39	1,896	484	447	134	91	3,091	8.8
Gadwall		70	54	144	6	99	373	1.1
Baldpate	3	383	399	4,324	120	1,905	7,134	20.2
Pintail	21	432	635	6,657	187	2,940	10,872	30.8
Green-winged Teal	7	190	360	1,433	138	2,790	4,918	13.9
Cinnamon Teal		6	27	26	2	206	267	0.7
Shoveller	10	233	355	3,747	145	2,495	6,985	19.8
Redhead		29	4	21	5	70	129	0.4
Canvasback		47	18	51	2	61	179	0.5
Ring-necked Duck		2	2	7		7	18	
Scaup	1	21	5	9	2	155	193	0.5
American Goldeneye	2	9	1	7		16	35	0.1
Bufflehead		22	4	13		25	64	0.2
Ruddy Duck		118	32	152	8	632	942	2.7
Fulvous Tree Duck						22	22	
Others and unclassified		3	100	2		9	114	0.3
Subtotal—ducks	83	3,461	2,480	17,040	749	11,523	35,336	100.0
Canada Goose	14	195	32	47	1	67	356	19.7
White-fronted Goose		13	285	107	7	11	423	23.4
Cackling Goose	47	46	376	20	41	3	533	29.5
Lesser Snow Goose		146	303	5	4	32	490	27.1
Others and unclassified		2	4				6	0.3
Subtotal—geese	61	402	1,000	179	53	113	1,808	100.0
Coots	0	18	111	504	58	166	857	
Grand totals	144	3,881	3,591	17,723	860	11,802	38,001	

TABLE 4

Species Composition of Waterfowl Killed on California Public Shooting Areas—1952

Species	Madeline Plains	Honey Lake	Colusa	Grizzly Island	San Luis Wasteway	Merced	Imperial	Totals	Percentage of kill
Mallard	248	1,361	1,506	1,580	182	198	157	5,232	7.0
Gadwall	8	110	90	190	43	21	126	588	0.8
Baldpate	23	158	1,039	6,158	515	179	1,678	9,750	13.0
Pintail	231	1,107	1,330	24,566	2,361	474	4,079	34,148	45.4
Green-winged Teal	60	157	821	1,558	1,052	214	2,858	6,720	8.9
Cinnamon Teal	----	9	47	6	15	7	320	404	0.5
Shoveller	71	376	1,120	7,963	2,163	373	3,510	15,576	20.7
Redhead	10	137	1	38	11	2	101	300	0.4
Canvasback	1	55	15	72	7	4	67	221	0.3
Ring-necked Duck	----	4	6	74	48	----	20	152	0.2
Scaup	----	14	7	51	18	3	253	346	0.5
American Goldeneye	----	10	3	7	----	2	26	48	----
Bufflehead	----	10	6	12	1	1	53	83	0.1
Ruddy Duck	6	75	42	428	256	23	825	1,655	2.2
Fulvous Tree Duck	----	----	----	----	----	----	12	12	----
Others and unclassified	----	2	7	24	1	13	7	54	----
Subtotal—ducks	658	3,585	6,040	42,727	6,673	1,514	14,092	75,289	100.0
Canada Goose	82	83	15	54	----	1	70	305	18.6
White-fronted Goose	1	9	200	143	6	11	33	403	24.5
Cackling Goose	152	11	205	54	4	79	----	505	30.7
Lesser Snow Goose	1	44	254	20	12	17	37	385	23.4
Others and unclassified	----	----	44	1	----	1	----	46	2.8
Subtotal—geese	236	147	718	272	22	109	140	1,644	100.0
Coots	3	24	74	1,127	186	94	354	1,862	----
Grand totals	897	3,756	6,832	44,126	6,881	1,717	14,586	78,795	----

TABLE 5

Species Composition of Waterfowl Killed on California Public Shooting Areas—1953

Species	Madeline Plains	Honey Lake	Gray Lodge	Colusa	Sutter	Welch Co-op	Grizzly Island	San Luis Waste-way	Merced	Los Banos	Imperial	Totals	Percentage of kill
Mallard	529	638	2,233	1,293	1,730	336	1,019	252	283	695	17	9,025	10.3
Gadwall	35	98	322	133	159	18	151	59	24	143	114	1,254	1.4
Baldpate	128	132	2,555	1,979	1,427	230	5,980	388	201	302	535	13,857	15.8
Pintail	318	417	1,731	1,602	3,270	380	23,132	3,392	438	536	921	36,137	41.2
Green-winged Teal	120	81	643	653	1,013	168	3,198	1,950	622	397	2,877	11,722	13.4
Cinnamon Teal	1	2	198	73	71	13	21	44	11	87	238	759	0.9
Shoveller	108	166	241	425	557	35	5,252	1,695	252	514	3,232	12,477	14.2
Redhead	21	99	4	5	7	------	34	6	------	1	20	197	0.2
Canvasback	2	74	3	12	6	9	73	8	2	7	17	213	0.2
Ring-necked Duck	------	6	1	------	13	2	30	18	------	22	------	92	0.1
Scaup	1	6	------	8	4	2	46	2	------	------	29	98	0.1
American Goldeneye	------	14	3	------	------	------	13	------	------	------	4	34	------
Bufflehead	------	6	------	3	------	------	11	2	------	------	23	45	------
Ruddy Duck	21	88	54	73	11	34	507	192	80	24	639	1,723	2.0
Others and unclassified	2	4	3	13	111	6	6	2	1	1	16	165	0.2
Subtotal—ducks	1,286	1,831	7,991	6,270	8,379	1,233	39,473	8,010	1,914	2,729	8,682	87,798	100.0
Canada Goose	108	124	10	18	27	36	37	6	14	------	472	852	11.0
White-fronted Goose	3	6	78	357	358	222	253	12	63	43	88	1,483	19.1
Cackling Goose	247	21	97	368	48	130	182	11	200	49	8	1,361	17.6
Lesser Snow Goose	2	180	297	549	614	1,109	6	13	5	96	1,015	3,886	50.1
Others	------	3	21	96	26	17	1	------	------	9	------	173	2.2
Subtotal—geese	360	334	503	1,388	1,073	1,514	479	42	282	197	1,583	7,755	100.0
Coot	9	31	55	128	109	375	1,266	262	59	144	210	2,648	------
Grand totals	1,655	2,196	8,549	7,786	9,561	3,122	41,218	8,314	2,255	3,070	10,475	98,201	------

waterfowl in that region and the local hunters make intensive use of whatever hunting sites are available. Furthermore, these two areas are located at too great a distance from the State's large population centers to attract many outside hunters.

In the balance of the State the situation is quite different. The public hunting areas are surrounded by many good hunting sites, so that local residents have a choice of places to hunt, either on their own property or on that of friends and relatives. Here the public hunting areas are located conveniently close to the population centers, making it possible for the city hunters to drive the round trip in one day.

Some of the data from Table 6 were used in Figures 4 through 7 to show graphically which public hunting areas were utilized by hunters from four of the large population centers. For these geographic illustrations, the public hunting areas were placed into five regional groups,

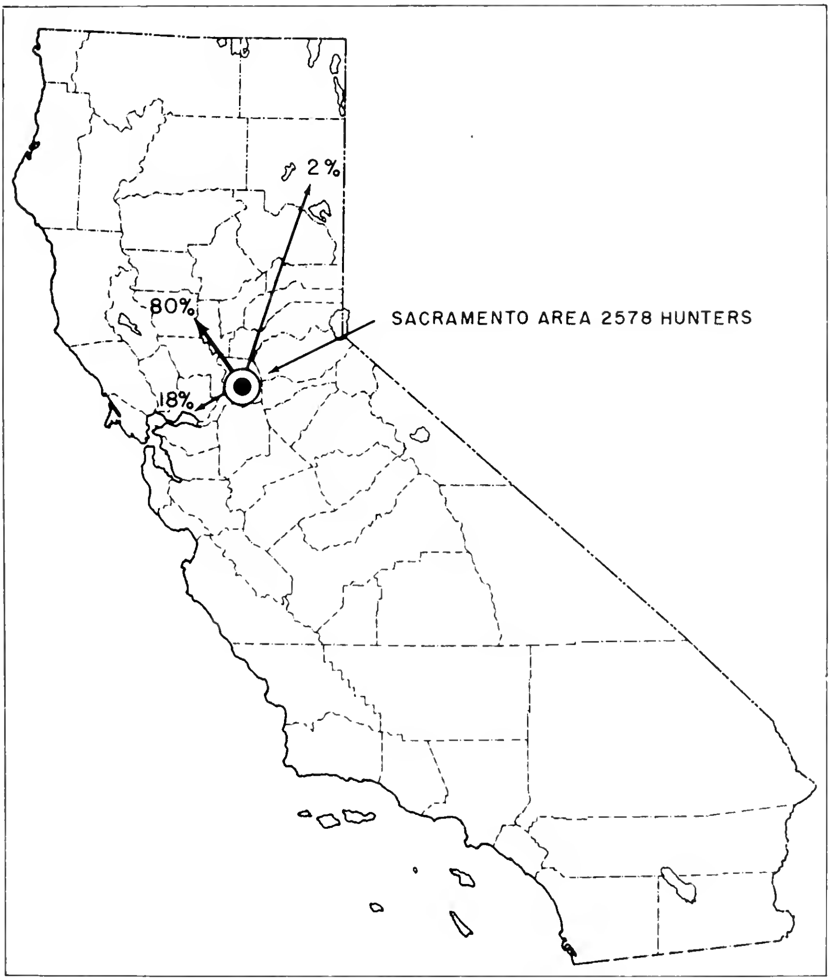

FIGURE 4. Map showing where Sacramento area hunters traveled to shoot on state-operated waterfowl hunting areas.

TABLE 6

County of Residence of Hunters Using California Waterfowl Public Shooting Areas—1953

	Madeline	Honey Lake	Gray Lodge	Colusa	Sutter	Welch Co-op	Grizzly Island	San Luis Wasteway	Merced	Los Banos	Imperial	Totals
Alameda	11	29	271	394	390	627	2,881	174	42	57	1	4,877
Alpine						1						1
Amador				1			2					3
Butte	10	17	**218**	12	13	7					1	278
Calaveras			1	1		5	2		7	1		17
Colusa			1	**18**	2	**30**	1					52
Contra Costa	37	7	191	294	160	463	2,513	17	10	17	1	3,710
El Dorado		3	3	12	5	1	3					27
Fresno	5	1				1	2	338	279	229	1	856
Glenn	3		6	1		6		1		3		20
Humboldt	8	8	5	2	3	26	5					57
Imperial			1			1		2			**215**	219
Inyo	5	1									2	8
Kern	6	2	1	2	1	1	1	12	6	8	2	42
Kings			2			1	1	13		3		20
Lake	7		6	21		59						93
Lassen	**397**	**2,232**	1				1					2,631
Los Angeles	29	50	43	66	32	60	32	116	74	85	3,008	3,595
Madera								14	64	2		80
Marin	1	13	76	104	7	55	375					631
Mariposa									3			3
Mendocino	6	10	5	50	3	65	8			21		168
Merced								**183**	**329**	**97**		609
Modoc	102	1					1					104
Mono		3			1							4
Monterey	15	4	9	2		3	3	768	30	317	4	1,155
Napa	2		7	69	35	76	411	6	2			608
Nevada		11	61	8	6	29	4			1		120
Orange	25	15	1	5		2	4	5			273	330
Placer	5	17	80	37	116	49	14	1				319
Plumas	182	320	5	1		2	2		1			513
Riverside			1	2	1	2			2		244	252
Sacramento	23	16	476	376	920	286	471	4	2	2	2	2,578

TABLE 6—Continued

County of Residence of Hunters Using California Waterfowl Public Shooting Areas—1953

	Madeline	Honey Lake	Gray Lodge	Colusa	Sutter	Welch Co-op	Grizzly Island	San Luis Wasteway	Merced	Los Banos	Imperial	Totals
San Benito	1					2		123	1	13		140
San Bernardino	26	6	1			1	4	1		4	269	312
San Diego	14		3	10		5	11		2	3	749	797
San Francisco	28	11	212	467	198	549	2,679	119	22	33	2	4,320
San Joaquin	5	4	6	20		17	171	122	50	4		399
San Luis Obispo	7	1	1	7		2	2	1		7		28
San Mateo	3	9	74	174	65	191	525	164	21	58	1	1,285
Santa Barbara	3		2	3		3	2	3	6	1	2	25
Santa Clara	17	8	24	66	11	107	166	811	32	507		1,749
Santa Cruz	7	2	2			2	3	188	28	141		373
Shasta	15	8	10	4		12		1		2		52
Sierra	15	47	5	1								68
Siskiyou	2	2										4
Solano		6	42	174	44	160	**1,270**			5	1	1,702
Sonoma	19	6	11	81	8	57	234	1			1	418
Stanislaus		14	2	12	3	7	9	318	118	65		548
Sutter	2		115	8	**123**	2		1				251
Tehama	7	9	2		4	5	8	1		3		39
Tulare		8	1			6	2	48	53	30	2	150
Tuolumne				5		9	7	8	9	3		41
Ventura	9		2			2	1	3	1	5	19	42
Yolo			27	42	33	39	23	8		6	1	179
Yuba			93	9	87	8						197
Nonresident	5	11	3				1	4				24
Unidentified			4	5	115	3	81			3		211
Totals	1,064	2,912	2,113	2,566	2,386	3,047	11,936	3,579	1,194	1,736	4,801	37,334

as follows: Northeastern California, which includes Madeline Plains and Honey Lake; Sacramento Valley, including Gray Lodge, Welch Co-op, Colusa, and Sutter; Grizzly Island; San Joaquin Valley, including San Luis Wasteway, Los Banos, and Merced; and the Imperial area.

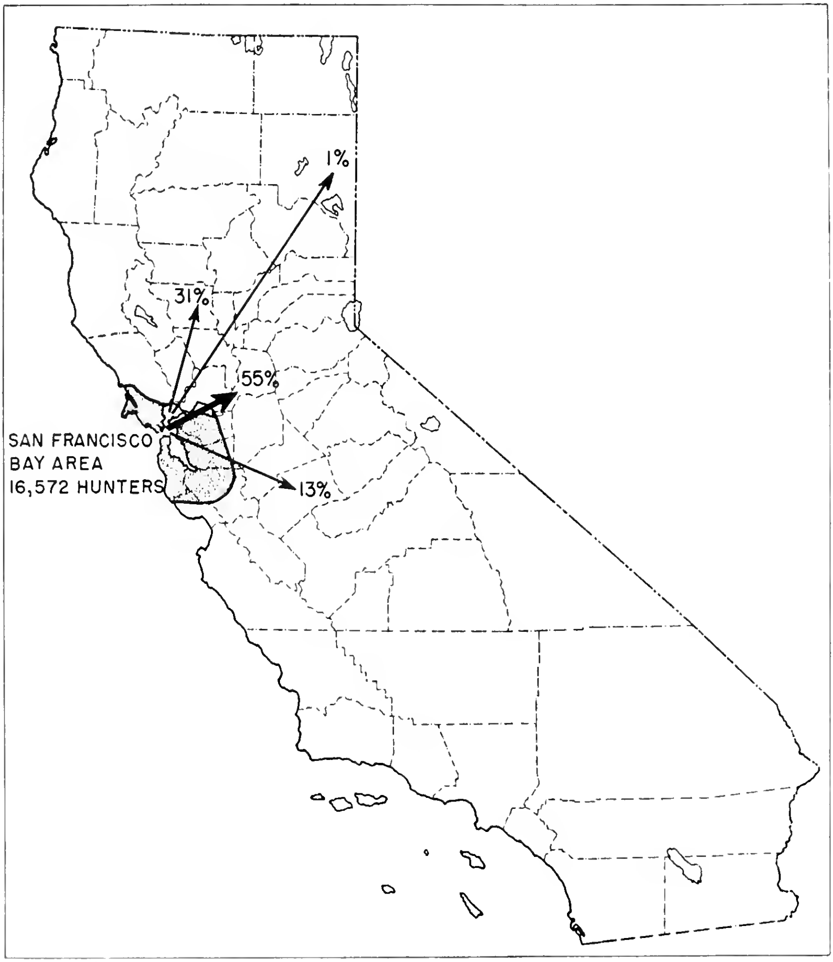

FIGURE 5. Map showing where San Francisco Bay area hunters traveled to shoot waterfowl on state-operated waterfowl hunting areas.

Naturally, every population center was represented by a few hunters at each hunting area, but to be considered in the figures the number had to amount to at least one percent of all the hunters from that urban area.

Of the 2,578 hunters from the Sacramento area (Figure 4), 80 percent went to the Sacramento Valley hunting areas. From Figure 5 it will be noted that 55 percent of the 16,572 hunters from the San Francisco Bay region went to Grizzly Island. Figure 6 shows that

FIGURE 6. Map showing where Fresno area hunters traveled to shoot on state-operated waterfowl hunting areas.

nearly all of the 856 hunters from the Fresno district hunted on the San Joaquin Valley areas. The 3,925 hunters from the Los Angeles area (Figure 7) did most of their hunting on the Imperial area, but were also represented on all of the other hunting grounds, with three percent even traveling the long distances to Madeline Plains and Honey Lake.

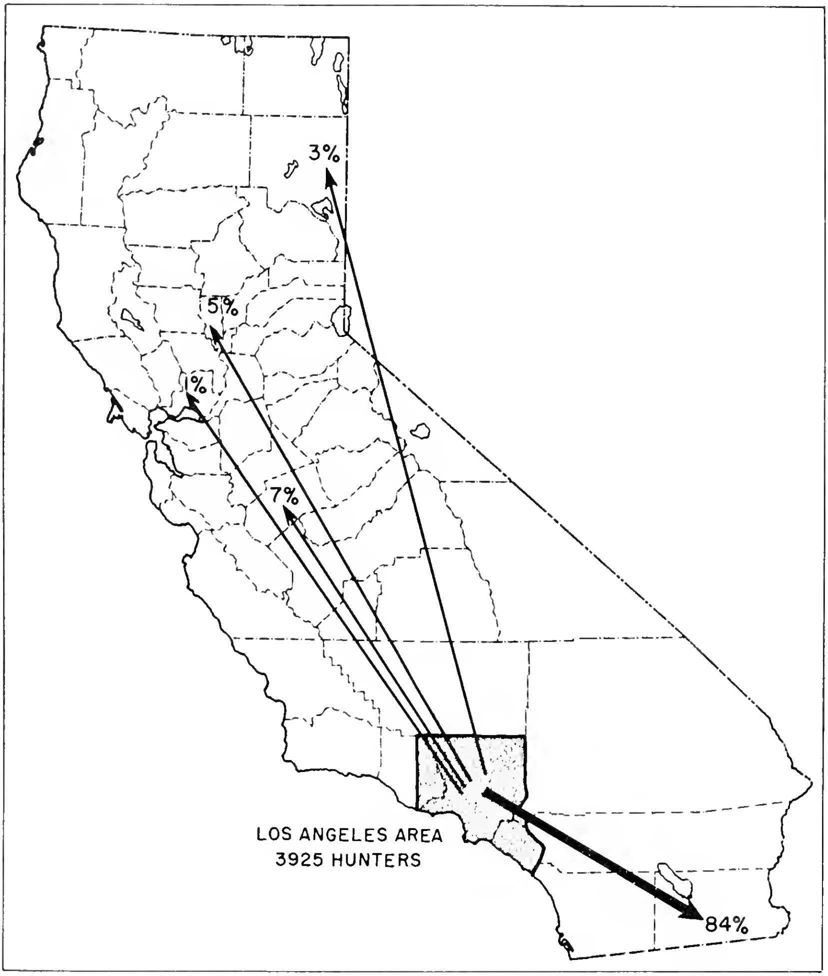

FIGURE 7. Map showing where Los Angeles area hunters traveled to hunt waterfowl on state-operated waterfowl hunting areas.

From the foregoing report, it may be seen that the program to furnish the unattached hunter with a place to shoot waterfowl has expanded considerably since 1948. Most of this expansion can be attributed to the acquisition of new areas and the subsequent accommodation of increased numbers of hunters. Even though additional areas may be acquired in the future, these public hunting areas can never hope to provide shooting space for every unattached hunter each shoot day of the waterfowl season. However, the program does provide some shooting for a great many hunters who otherwise would be without a place to hunt.

SUMMARY

In 1948 only three hunting areas totaling 7,730 acres were taking part in the program to provide the unattached hunter with a place to hunt waterfowl. By 1953 the California Department of Fish and Game had expanded this program to 12 areas totaling 29,775 acres. The areas extend over the State from the Mexican border nearly to the Oregon state line. During this six-year period the number of hunters accommodated on the areas increased from 2,037 to 37,334. Hunters from the large population centers made more use of the areas than did local hunters.

The hunting success has progressively increased from 1.5 birds per hunter in 1948 to 2.6 birds per hunter in 1953. The pintail, the most common duck in California, predominated in the total kill, but it was not the top ranking duck on all areas. On most areas the kill reflected to some degree the composition of the local duck population.

The public hunting program can never hope to provide shooting space for every unattached hunter each shoot day of the waterfowl season, but it will furnish some shooting for a great many hunters who otherwise would be without a place to hunt.

REFERENCES

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APPENDIX

1953 Waterfowl Management Area Regulations Adopted by the California Fish and Game Commission

The following regulations promulgated under Sections 328, 338 and 339 of the Fish and Game Code shall apply to all waterfowl management areas operated for public shooting by the California Department of Fish and Game.

a. Use of any state-operated waterfowl management area shall be at the sole risk of the permittee and neither the State of California, cooperating agencies, nor any of its officers, agents, servants or employees shall be liable in damage to the permittee in any manner whatsoever in connection with such use while the permittee is on, or en route to or from, the area. Each permittee for himself, his heirs, administrators and assigns shall sign a waiver of all claims and demands against the State or its agents, servants or employees for any and all damages or loss arising in any manner out of and in connection with the use of the area by the permittee.

b. The state employee in charge of each waterfowl management area shall be responsible for the enforcement of these regulations on that area. These regulations shall be incorporated into and become a part of all permits and in applying for a permit each applicant shall state in writing that he has read, understood and agrees to be bound thereby.

c. Subject to all conditions of these regulations, permits to shoot on state-operated waterfowl management areas will be issued only to holders of valid hunting licenses, and will be issued only by authorized employees of the Department of Fish and Game. Possession of a valid Federal Migratory Waterfowl Hunting Stamp is required of all migratory waterfowl hunters 16 years of age or over.

d. The State reserves the right to refuse to issue a permit to anyone and to revoke any permit and to eject the holder forthwith from the area for disorderly conduct, intoxication, or for any reason when it appears that the safety or welfare of the area, or that of other permittees, is endangered. Decision of the authorized employee of the Department of Fish and Game in this respect shall be final.

e. Except at Napa Marshes (Leslie Salt Company lands), permits for each shooting day will be issued in the order of registration but never at any one time in a number exceeding the shooting capacity of the area as determined by the state employee in charge of each area. For Napa Marshes shooting permits for the waterfowl season will be issued at the offices of the Department of Fish and Game in San Francisco and Sacramento and at designated license agents in the towns of Napa and Vallejo.

f. Except at Napa Marshes, no person shall be entitled to more than one shooting permit on any one waterfowl management area during each hunting season, except that when a vacancy or vacancies shall exist at the close of any registration period, permits may be issued to persons actually present who have previously held a permit. (In cases where the waterfowl season is divided into separate periods (split season) each period shall be considered to be a hunting season.) For the purpose of determining priority under this section, such priority will only be honored for those present one hour before legal shooting time. At Napa Marshes each permit holder will be entitled to hunt every day of the legal waterfowl season.

g. Minors to 16 shall be accompanied by an adult legally responsible for him or her and said adult shall sign the permit with and in behalf of such person.

h. Any unauthorized person, or a person not in possession of a valid permit, who enters upon a state-operated waterfowl management area shall be deemed a trespasser.

i. Only migratory waterfowl may be legally taken by permittees on designated shooting days during the open waterfowl hunting season, except at Honey Lake, Los Banos, and Grizzly Island waterfowl management areas where pheasant hunting will be permitted in the event the waterfowl and pheasant hunting seasons overlap in dates. In the event the waterfowl and pheasant hunting seasons do not overlap in dates, pheasant hunting will be permitted on the Madeline, Honey Lake, Grizzly Island, Imperial, Los Banos, and Gray Lodge waterfowl management areas.

j. Any portion of a state-operated waterfowl management area, or any adjoining lands under control of the Department of Fish and Game, may be closed to hunting and trespass by the Department of Fish and Game by legally posting notice of the same.

k. Shooting days on state-operated waterfowl management areas, except Imperial Waterfowl Refuge and Napa Marshes, shall be Wednesdays, Saturdays, Sundays, the opening and closing dates of each legal waterfowl hunting season, and Armistice Day, Thanksgiving Day and election day when these holidays fall within the legal waterfowl season. All state-operated waterfowl management areas will be closed to hunting on New Year's Day and Christmas, unless such days fall on the last day of the season.

Napa Marshes will be open to hunting by permit every day of the legal waterfowl season.

l. On all state-operated waterfowl management areas no entry to hunt will be allowed after 2 p. m.

m. Shooting fees shall be as follows:

1. Madeline Plains and Honey Lake waterfowl management areas, no fee.
2. Napa Marshes waterfowl management area, $3 per season for persons over the age of 16 years. Minors to 16 and accompanied by adults, $1 per person. No daily permits will be sold.
3. Imperial waterfowl management area, $2 per day for nonblinded areas, $5 per day for blinded areas, on a first-come, first-served basis for persons over the age of 16 years. For persons up to 16 years of age $2.50 per day will be charged for blinds. Such persons will be accompanied by an adult.
4. All other waterfowl management areas, $2 per day for persons over the age of 16 years.

n. Applicants for permits to hunt on areas must be registered at designated checking stations on designated shooting days or may apply in advance for the Imperial waterfowl management area. For the Imperial waterfowl management area applicants may register in person at the following designated checking stations on day preceding shoot day:

1. Los Angeles office of the Department of Fish and Game.
2. San Diego office of the Department of Fish and Game.
3. Headquarters of the Imperial waterfowl management area (Hazard Unit).

o. On the Imperial waterfowl management area, shooting hours shall be as follows:

1. If the following day is not a designated shooting day—from legal opening time until 2 p.m.
2. If the day following is a designated shooting day—from legal opening time until 12 noon, except opening day on which day shooting hours shall be from 12 noon until legal closing time.

p. On all other areas, shooting hours shall be from legal opening time until legal closing time.

q. The Commission may defer the opening to public access of any or all of the waterfowl management areas operated by the State of California when such action may be desirable from the standpoint of protection of agricultural crops.

THE DIGESTIBILITY OF CERTAIN NATURAL AND ARTIFICIAL FOODS EATEN BY DEER IN CALIFORNIA[1]

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INTRODUCTION

Deer management in California is concerned with maintaining deer herds at a level consistent with the proper use of the available forage on their ranges. It aims at maintenance of an optimum balance between the animals and the forage plants on which they feed: one at which the animals will flourish because of availability of foods adequate in both quality and quantity of nutrients and one at which the forage species will flourish because sufficient vegetative growth is left uncropped to enable the plants to maintain vigorous growth and to reproduce.

A variety of plants is eaten by deer, some to a much greater extent than others. Chemical analyses often fail to show why forage of apparently low food value is preferred to browse analyzing much higher in nutrients.

Deer managers are aware of the necessity of keeping adequate forage available for deer. There is need, however, for more information on the nutrient values of various forage species, singly and in combination.

Chamise (*Adenostoma fasciculatum*) and interior live oak (*Quercus wislizenii*) are two of the important browse species available to deer in the northern Coast Range. Big sage (*Artemisia tridentata*) and bitterbrush (*Purshia tridentata*) are major items in the diet of the Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) wintering in the Great Basin area (Longhurst et al., 1952). In this paper all references to live oak will refer to interior live oak.

Since the quantity of the vegetation is not always the limiting factor in deer nutrition, it follows that the actual quality or nutritive value of the important species should be determined.

A series of experiments was planned in an attempt to determine (1) the protein digestibilities and the total digestible nutrients of alfalfa hay, chamise, live oak, bitterbrush, sagebrush, barley, and oats, (2) the amount of digestible energy necessary to maintain a deer, (3) the

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This study was conducted by Federal Aid in Wildlife Restoration Project California W-25-R, "Food Habits Investigations." The writers wish to express appreciation to Jack Romera, who constructed the digestion trial cages and who assisted in the early conduct of the experiments. Appreciation is also due personnel of the Yountville Game Farm and Honey Lake Refuge for their assistance in setting up equipment and to personnel of Region 1 who helped with the trapping of wild deer.

amount of water used by a deer, and (4) the comparative values of the aforesaid feeds in their ability to maintain a deer and to supply available energy.

The following is a preliminary report on the nutritive values of these feeds.

PREVIOUS INVESTIGATIONS

In the West, only Smith (1950, 1952) and Hagen (1953) have reported digestion trial results on deer. Maynard et al. (1935) and Forbes et al. (1941) have reported on white-tailed deer (*Odocoileus virginianus*).

Some investigators have conducted feeding trials on deer in studies of weight change and intake or palatability of various diets. Some of these have been Davenport (1939), Nichol (1938) and Doman and Rasmussen (1944).

Other investigators have reported chemical analyses of deer browse which serve to reflect the possible food value of a given plant through the seasons. These workers include Gordon and Sampson (1939), Hellmers (1940), Reynolds and Sampson (1943), Aldous (1945), Einarsen (1946), Swift (1948), Hagen (1953), and others.

In general, these investigators report a higher protein content during the growing season and a rapid decline in protein as the plants mature. Einarsen (1946) postulates a minimum intake of 5 percent total crude protein for the maintenance of deer. It is the belief of the authors of the present paper that total protein is in itself an inadequate expression of the nutritive value of a plant.

FIGURE 1. General view of digestion trial cage.

METHODS

A number of digestion trial cages (Figures 1 and 2) were constructed, as follows.

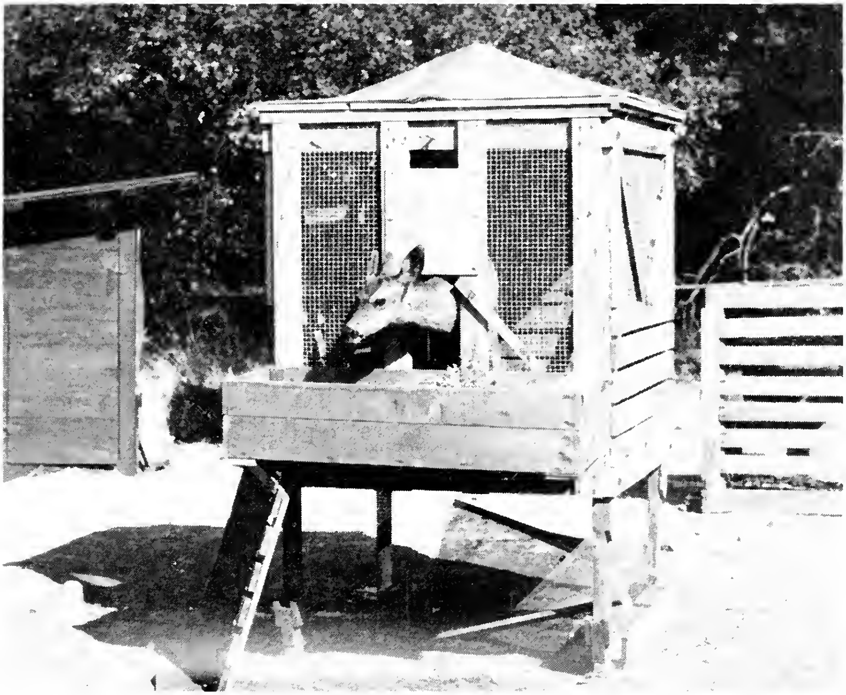

FIGURE 2. Digestion triol cage in use, with feed box cover removed to show the deer.

Four-foot cubes were constructed with sides and tops of 1-inch by 4-inch fir boards. The floor was made of 9-gauge, ½-inch mesh wire screen. An inclined piece of window screen was placed beneath the floor, so that falling feces were deflected into a collecting trough. These trials did not require the collection of urine, which passed through the window screen and was absorbed in the ground with a minimum of contact with the feces.

The cages were made in panels, so that they could be easily dismantled and set up by one man and readily transported from one place to another in a one-half ton pickup truck.

Deer were obtained either through live trapping or through use of deer raised in captivity and fed on a diet of rolled barley and alfalfa hay. The following study diets were used: black-tailed deer (*Odocoileus hemionus columbianus*) were fed live oak (*Quercus wislizenii*) and chamise (*Adenostoma fasciculatum*). Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) were fed bitterbrush (*Purshia tridentata*) and big sage (*Artemisia tridentata*). Alfalfa hay and alfalfa grain mixes were fed to both groups of animals.

Alfalfa hay and the grains were chosen to (1) standardize experimental techniques, (2) determine minimal food and energy intakes, and (3) determine relative value as possible winter feed supplements.

The natural vegetation was all fed fresh daily and consisted of those parts of the plant which deer were observed to use normally. This usually meant that the terminal three to six inches of the stem and leaves were collected. Collection of chamise and bitterbrush was a difficult and tedious task.

CONDUCT OF EXPERIMENTS

The animal was weighed and placed in the digestion trial cage. Measured amounts of water and feed were given daily about 10 a.m. At the time of feeding any material remaining from the previous day's feeding was carefully collected and weighed and water use measured. An attempt was made in these experiments to keep just as much as the deer would eat before them at all times.

Theoretically, a digestion trial requires a constant intake fed at a maintenance level. Such procedure was not possible in the deer feeding experiments, since the animals tended to vary their daily intake considerably. This should be considered in interpreting the digestibilities reported below.

All deer were fed the experimental diet for at least five days before the actual study started, so that the digestive tract might be cleansed of its previous diet. After this initial feeding period, feces were collected for at least five days and all intake and fecal output were recorded daily.

Where necessary, an aliquot portion of each day's feeding was taken, weighed, and held overnight and weighed to determine any necessary correction for changes in weight of remaining feed due to moisture loss.

Feces were weighed (wet weight was only approximate due to drying before collection could be made), air dried for two to four days to prevent mold, sacked, and transported to the laboratory for analyses.

Representative samples of the materials fed were taken at intervals throughout the experiment and pooled for chemical analyses.

Upon completion of the digestion trial and at intervals during the experiment all deer were weighed.

The chemical methods followed those of the Association of Official Agricultural Chemists (1950). The net energy determinations were made with a Parr peroxide bomb calorimeter, using standard techniques.

The digestion trials are based on the determination of total digestible nutrients (TDN) by calorimetric means. This meant that only total protein, ether extract, and total ash had to be determined in addition to the energy content in calories.

The calorimetric determination of TDN follows the suggestions and methods of Overman and Gaines (1933) and Lofgreen (1951). This method does not take into account losses of energy in the animal due to rumen fermentations and loss of methane. This will be discussed later in the paper.

All determinations are on an oven dry basis; and since the percentage of moisture is given it is easy to convert any given value in the tables to the concentration in the original food or feces.

The length of digestion trial in days gives the total time on the experimental diet. The grams average weight of feces per day given in the tables is only approximate and is included only as supplemental information.

TABLE 1

Summary of Daily Intakes and Total Weight Changes
(Dry Weight Basis)
Alfalfa Hay + Oats

Digestion trial number	Deer number	Sex and age	Days length of digestion trial	Pounds weight at start of digestion trial	Pounds weight change	Grams intake per day of			Approximate grams average weight of feces per day
						Alfalfa	Oats	Water	
1	303	M F	10	50.0	—1.0	24	465	1,400	70
2	214	M F	14	50.0	+3.0	122	448	1,518	103
3	301	M F	13	64.0	—1.0	98	660	1,414	159

Average 1,062 grams dry matter/cwt./day or 2.3 pounds dry matter/cwt./day.

2,682 grams water/cwt./day or 5.9 pounds water/cwt./day

Weight change per day averages +.03 pounds.

RESULTS OF EXPERIMENTS

Three male black-tailed deer about one year old, raised in captivity and weighing 50 to 64 pounds were selected for the first trials. Alfalfa hay and rolled oats were chosen as the first study diet, since deer in the holding pens were known to do well on the mixture, and it was believed that the methods of the digestion trial should be standardized on feeds for which many data on cattle and sheep nutrition are available (Morrison, 1950). The alfalfa hay-oat diet appeared to be highly relished and was utilized very effectively by deer.

TABLE 2

Chemical Analyses of Food and Feces
(Dry Weight Basis)
Alfalfa + Oats

Digestion trial number	Item	Calories per gram	Percentage crude protein	Percentage total ash	Percentage moisture	Percentage ether soluble extract
1 and 2	Alfalfa	5.1	17.1	7.7	10.0	1.7
3	Alfalfa	4.8	19.1	8.0	10.0	2.0
1, 2, and 3	Oats	4.8	12.5	4.1	7.0	5.0
1	Feces	5.0	15.1	13.9	191.0	----
2	Feces	5.0	16.3	12.5	171.0	----
3	Feces	4.6	13.9	13.3	177.0	----

TABLE 3

Summary of Caloric Intake and Digestibilities
(Dry Weight Basis)
Alfalfa + Oats

Digestion trial number	Deer number	Total daily caloric intake	Digested daily caloric intake	Percentage coefficient of digestion of protein	Percentage total digestible nutrients
1	30	2,354	2,035	82.0	86.7
2	214	2,772	2,255	78.0	81.7
3	301	3,638	2,906	78.3	80.8
Average		----	----	79.4	83.0
Average/cwt.		5,310	4,547	----	----

A second group of experiments was set up, using two yearling males and two adult does, one of which (No. 302) bore twin doe fawns (7.0 pounds each) 50 days later. These deer were all black-tailed deer raised in captivity. The four deer were placed on an alfalfa-rolled barley diet. Barley was chosen because this grain has more of a history of use in winter feeding and was more common in the California markets.

TABLE 4

Summary of Daily Intakes and Total Weight Changes
(Dry Weight Basis)
Alfalfa Hay + Barley

Digestion trial number	Deer number	Sex and age	Days length of digestion trial	Pounds weight at start of digestion trial	Pounds weight change	Grams intake per day of			Approximate grams average weight of feces per day
						Alfalfa	Barley	Water	
4	209	M Y	14	76.0	+1.5	161	695	1,498	140
5	210	F A	14	102.0	+2.5	148	661	1,362	153
6	303	M F	16	56.0	+3.0	138	579	1,362	149
7	302	F A	16	103.5	0.0	326	567	1,861	200

Average 1,015 grams dry matter/cwt./day or 2.2 pounds dry matter/cwt./day.
1,884 grams water/cwt./day or 4.1 pounds water/cwt./day.
Weight change per day averages +0.12 pounds.

TABLE 5

Chemical Analyses of Food and Feces
(Dry Weight Basis)
Alfalfa + Barley

Digestion trial number	Item	Calories per gram	Percentage crude protein	Percentage total ash	Percentage moisture	Percentage ether soluble extract
4 and 5	Alfalfa	4.8	19.1	8.0	10.0	2.0
6 and 7	Alfalfa	5.1	16.9	6.6	10.0	1.7
4, 5, 6, and 7	Barley	4.7	10.2	2.6	9.3	1.4
4	Feces	5.0	18.3	4.3	174.0	----
5	Feces	4.8	16.3	12.6	126.0	----
6	Feces	4.7	16.5	10.2	26.0	----
7	Feces	4.7	16.1	13.3	46.0	----

TABLE 6

Summary of Caloric Intake and Digestibilities
(Dry Weight Basis)
Alfalfa + Barley

Digestion trial number	Deer number	Total daily caloric intake	Digested daily caloric intake	Percentage coefficient of digestion of protein	Percentage total digestible nutrients
4	209	4,039	3,384	72.8	81.5
5	210	3,817	3,081	73.9	79.4
6	303	3,425	2,725	69.7	78.1
7	302	4,328	3,371	70.6	76.4
Average	----	----	----	71.8	78.9
Average/cwt.	----	4,849	1,141	----	----

Compared to the alfalfa-oat experiments, the diet appears consistently less digestible in total nutrients as well as in protein. No weight losses were incurred, however, as opposed to two losses and one gain on the alfalfa-oat diet. The alfalfa-barley diet appears to be highly palatable and nutritious.

During these two experiments the deer tended to select leaves and non-stemmy material and to leave the coarse stems. This introduced a certain error which was minimized by feeding very little more than the deer would clean up. Also, by preliminary screening of the alfalfa, a mixture of leaves and finer stems was obtained to serve as representative samples for analyses.

Since the experimental methods appeared to be satisfactory, the next trials were conducted on stump sprouts of live oak (*Quercus wislizenii*), using branch tips and leaves. Two 13-month-old male black-tailed deer, which had been raised in captivity, were used in this experiment. Because the deer in the holding pens appeared to relish live oak, no difficulty was expected. The opposite proved to be the case.

TABLE 7

Summary of Daily Intakes and Total Weight Changes
(Dry Weight Basis)
Live Oak

Digestion trial number	Deer number	Sex and age	Days length of digestion trial	Pounds weight at start of digestion trial	Pounds weight change	Grams intake per day of		Approximate grams average weight of feces per day
						Oak	Water	
8	214	M Y	27	53.0	−12.0 (approx.)	198	1,135	149
9	301	M Y	32	60.5	−14.5	191	999	133

Average 342 grams dry matter cwt./day or 0.75 pounds dry matter/cwt./day.

1,897 grams water cwt./day or 4.2 pounds water cwt./day.

Weight change per day averages 0.45 pounds.

TABLE 8

Chemical Analyses of Food and Feces
(Dry Weight Basis)
Live Oak

Digestion trial number	Item	Calories per gram	Percentage crude protein	Percentage total ash	Percentage moisture	Percentage ether soluble extract
8 and 9	Live oak	4.9	14.8	2.9		4.3
8	Feces	5.6	12.2	5.3	75.0	----
9	Feces	5.3	15.2	6.8	57.0	----

TABLE 9

Summary of Caloric Intake and Digestibilities
(Dry Weight Basis)
Live Oak

Digestion trial number	Deer number	Total daily caloric intake	Digested daily caloric intake	Percentage coefficient of digestion of protein	Percentage total digestible nutrients
8	214	970	145	38.1	15.7
9	301	396	230	28.4	25.8
Average	----	----	----	33.3	20.8
Average/cwt.	----	1,685	327	----	----

Deer No. 214 developed an infected jaw and had to be shot. Deer No. 301 died in its cage. The condition of the deer was poor, as evidenced by the general appearance: red, jelly-like bone marrow and the total absence of visible fat anywhere in the body. It appears that the deer simply would not eat enough to keep alive. Only one-third of the expected amount of dry material was ingested. The food appeared to be unpalatable.

Three more experiments were devised and set up near Lakeport, Lake County, in order to test the digestibilities of new growth of three-year-old live oak and chamise, singly and in combination. Two males and one stag, each about 13 months old, were used. All were black-tailed deer raised in captivity.

TABLE 10

Summary of Daily Intakes and Total Weight Changes

(Dry Weight Basis)

Live Oak and Chamise

Digestion trial number	Deer number	Sex and age	Days length of digestion trial	Pounds weight at start of digestion trial	Pounds weight change	Grams intake per day of			Approximate grams average weight of feces per day
						Oak	Chamise	Water	
13	303	M Y	18	59.0	14.0	218		1,544	81
12	301	M Y	18	77.0	-16.5	190	115	2,633	130
14	305	Stag Y	10	47.0	13.0	----	124	2,106	52

Average 351 grams dry matter/cwt./day or 0.77 pounds dry matter/cwt./day.

3,718 grams water/cwt./day or 8.2 pounds water/cwt./day.

Weight change per day averages 1.0 pounds

TABLE 11

Chemical Analyses of Food and Feces

(Dry Weight Basis)

Live Oak and Chamise

Digestion trial number	Item	Calories per gram	Percentage crude protein	Percentage total ash	Percentage moisture	Percentage ether soluble extract
12 and 13	Live oak	4.9	7.1	1.7	153.0	5.7
12 and 14	Chamise	5.1	8.1	2.6	173.0	9.2
12	Feces	5.5	15.9	3.1	89.0	----
13	Feces	5.5	13.4	4.3	25.0	----
14	Feces	5.9	19.5	4.2	10.0	----

TABLE 12

Summary of Caloric Intake and Digestibilities
(Dry Weight Basis)
Live Oak and Chamise

Digestion trial number	Deer number	Total daily caloric intake	Digested daily caloric intake	Percentage coefficient of digestion of protein	Percentage total digestible nutrients
12	304	1,552	836	9.2	56.1
13	303	1,068	621	31.9	61.7
14	305	670	361	negative	58.8

The deer did not appear to relish the diet. This is reflected in the consumption figures, and the deer were in very poor shape at the end of the trials.

The next set of experiments was carried out during the winter of 1953-54 in Lassen County. The actual digestion trials were conducted at the Honey Lake Waterfowl Management Area near Wendel. Mule deer were live-trapped directly from the winter range and taken to the area headquarters for study.

The first study diet used was bitterbrush. This was during the months of November and December, 1953, when bitterbrush was the chief item in the diet of deer on the winter range, as shown by stomach analyses (Lassen et al., 1952). Two deer were used in these first experiments and two more deer were tested in March, 1954, when ordinarily the consumption of bitterbrush has diminished.

TABLE 13

Summary of Daily Intakes and Total Weight Changes
(Dry Weight Basis)
Bitterbrush

Digestion trial number	Month	Deer number	Sex and age	Days length of digestion trial	Pounds weight at start of digestion trial	Pounds weight change	Grams intake per day of		Approximate grams average weight of feces per day
							Bitterbrush	Water	
25	Nov.	319	M F	16	69.0	−5.0 (approx.)	632	801	278
28	Dec.	268	M F	28	69.0	−7.0	791	746	377
18	Mar.	331	M F	29	58.0	−4.0	625	1,551	281
19	Mar.	335	M A	29	90.5	−8.5	661	767	265
Average per day						0.25	678	967	
Average per 100-pound deer per day (pounds)							2.2	3.2	
Average per 100-pound deer per day (grams)							999	1,453	

TABLE 14

Chemical Analyses of Bitterbrush and Feces
(Dry Weight Basis)

Digestion trial number	Item	Calories per gram	Percentage protein	Percentage ash	Percentage water	Percentage ether soluble extract
25	Bitterbrush	5.6	9.6	2.5	94.0	7.9
25	Feces	6.1	8.6	4.4	45.0	----
28	Bitterbrush	5.6	8.1	2.3	90.0	3.2
28	Feces	6.0	8.8	3.9	50.0	----
48	Bitterbrush	5.5	9.4	2.4	72.0	4.9
48	Feces	5.9	8.9	4.6	64.0	----
49	Bitterbrush	5.5	9.4	2.4	72.0	4.9
49	Feces	5.8	8.9	4.6	51.0	----

TABLE 15

Summary of Caloric Intake and Digestibilities
(Dry Weight Basis)
Bitterbrush

Digestion trial number	Coefficient of digestion of protein	Percentage total digestible nutrients	Daily caloric intake	Digested daily caloric intake
25	60.5	55.6	3,539	1,841
28	48.3	49.8	4,430	2,168
48	56.1	53.7	3,438	1,779
49	62.2	60.0	3,654	2,117
Average	56.8	54.8	----	----
Average per 100-pound deer per day	----	----	5,371	2,805

Bitterbrush appeared to differ little in digestibility whether collected in November or in March. The protein content was relatively unchanged, as was the energy content. The 2.2 pounds of dry material ingested per 100 pounds of deer per day is about as expected, but the slight weight loss in all cases implies that the daily intake was too low for maintenance.

Water intake during these trials was fairly uniform, the average being 3.2 pounds of water per 100-pound deer per day.

The second series of experiments was carried out with sagebrush during January, February, and March of 1954, the months when deer on the range usually consume considerable quantities of this browse (Lassen et al., 1952).

TABLE 16

Summary of Daily Intakes and Total Weight Changes
(Dry Weight Basis)
Sagebrush

Digestion trial number	Month	Deer number	Sex and age	Days length of digestion trial	Pounds weight at start of digestion trial	Pounds weight change	Grams intake per day of		Approximate grams average weight of feces per day
							Sagebrush	Water	
30	Jan.	*268	M F	16	61	—15	157	1,072	101
31	Jan.	323	F F	15	68	—11	159	1,072	65
32	Jan.	327	F F	14	63	— 7.5	63	584	35
33	Jan.	326	F A	15	111	—22	29	792	40
34	Jan.	328	M F	15	61	—11	109	973	65
43	Mar.	329	F A	33	119	—27	68	988	24
Average per day						0.87	98	913	
Average per 100-pound deer per day (pounds)							0.6	2.7	
Average per 100-pound deer per day (grams)							272	1,226	

* Deer No. 268 died in its cage. There was no obvious pathology. The deer was extremely emaciated and had red gelatinous bone marrow, and no body fat.

TABLE 17

Chemical Analyses of Sagebrush and Feces
(Dry Weight Basis)

Digestion trial number	Item	Calories per gram	Percentage protein	Percentage ash	Percentage water	Percentage ether soluble extract
30, 31, 32, 33 and 34	Sagebrush	5.8	11.2	4.1	120.0	13.9
30	Feces	5.8	11.8	9.4	145.0	
31	Feces	5.9	10.4	7.2	138.0	
32	Feces	6.1	10.6	6.5	68.0	
33	Feces	5.5	14.2	13.3	215.0	
34	Feces	5.4	12.3	12.7	161.0	
43	Sagebrush	5.5	11.8	3.3	183.0	14.5
43	Feces	5.4	22.8	11.6	104.0	

Sagebrush apparently varied little in chemical composition or digestibility from January to March, but extreme differences in response of the deer to the straight sagebrush diet tend to mask any real differences in digestibility.

The average intake per 100-pound deer per day was only 0.6 pounds of dry matter, considerably below what was expected from other diets. It is obvious that the deer would lose weight, and they did to the extent of more than a pound a day.

TABLE 18

Summary of Caloric Intake and Digestibilities
(Dry Weight Basis)
Sagebrush

Digestion trial number	Coefficient of digestion of protein	Percentage total digestible nutrients	Daily caloric intake	Digested daily caloric intake
30	32.2	40.3	911	327
31	62.2	67.3	922	552
32	47.7	47.1	365	154
33	negative	negative	168	—55
34	33.6	50.1	632	284
43	32.1	74.9	374	247
Average (omitting negative values)	41.6	55.9	----	----
Average per 100-pound deer per day	----	----	958	453

The chief observation made here was the obvious unpalatability of the sagebrush. Whether the deer would have lost weight or would have shown a different digestibility of this forage plant if they could have been induced to eat more, remains a debatable point. Feces were soft and poorly formed in five cases. One deer (No. 326) had an extremely liquid diarrhea, which cleared up in 24 hours after the animal was placed on alfalfa hay.

The sagebrush oil content may influence the palatability of the browse as well as the determination of TDN with the bomb calorimeter. Sagebrush, oven dried, had an ether soluble extract, as given in Table 17—about 14 percent. However, sagebrush dried in a dessicator contained about 21 percent of ether soluble substances. Sagebrush which was steam distilled yielded about 12 percent steam volatile substances. Since these substances are chiefly essential oils of a different composition than fats, TDN values based on calorimetric determinations may be expected to be in error (Cook et al., 1951). However, the error is probably not significant in this instance, due to the large differences in the individual response of the deer. Sagebrush oil has a potential deleterious action on rumen microorganisms (Carlson et al., 1946; Bissell, 1952).

Water intake during these trials averaged 2.7 pounds per 100-pound deer per day.

The third set of feeding experiments was conducted with a diet of straight alfalfa hay.

Five deer were used, two being domesticated black-tailed deer (Nos. 308 and 312) and three wild mule deer. Two of the latter were directly trapped from the range, and the other (No. 335) had previously been used on a bitterbrush digestion trial.

TABLE 19

Summary of Daily Intakes and Total Weight Changes
(Dry Weight Basis)
Alfalfa

Digestion trial number	Month	Deer number	Sex and age	Days length of digestion trial	Pounds weight at start of digestion trial	Pounds weight change	Grams intake per day of		Approximate grams average weight of feces per day
							Alfalfa	Water	
26	Nov.	308	M F	15	38	+2	731	1,670	221
27	Nov.	312	M F	13	39	none	809	1,845	217
52	Mar.	338	M Y	10	62	—2 (approx.)	361	1,822	108
53	Mar.	339	M Y	24	57	—6.5	378	1,167	148
57	Mar.	335	F A	21	83	—6.5	731	2,639	279
Average per day (mule deer)						—0.26			
Average per day (black-tailed deer)						+0.07			
Average per 100 pounds of deer per day (pounds), all deer							2.7	7.6	
Average per 100 pounds of deer per day (grams), all deer							1,226		
Average per 100 pounds of deer per day (pounds), blacktails (domesticated)							4.4		
Average per 100 pounds of deer per day (grams), blacktails (domesticated)							1,998		
Average per 100 pounds of deer per day (pounds), mule deer (wild)							1.6		
Average per 100 pounds of deer per day (grams), mule deer (wild)							726		

Deer Nos. 308 and 312 are black-tailed deer.
Deer Nos. 338, 339, and 335 are mule deer.

TABLE 20

Chemical Analyses of Alfalfa and Feces
(Dry Weight Basis)

Digestion trial number	Item	Calories per gram	Percentage protein	Percentage ash	Percentage water	Percentage ether soluble extract
26 and 27	Alfalfa	4.8	14.3	7.0	9.3	1.6
26	Feces	4.8	11.2	13.9	96.0	----
27	Feces	4.9	13.2	12.5	65.0	
52	Alfalfa	4.7	15.9	8.4	15.8	4.8
52	Feces	4.5	14.1	20.0	104.0	- -
53 and 57	Alfalfa	4.9	15.2	9.5	15.8	1.5
53	Feces	4.4	12.5	21.2	63.0	----
57	Feces	4.1	11.8	24.0	58.8	---

TABLE 21

Summary of Caloric Intake and Digestibilities
(Dry Weight Basis)
Alfalfa

Digestion trial number	Coefficient of digestion of protein	Percentage total digestible nutrients	Daily caloric intake	Digested daily caloric intake
26	70.0	67.1	3,509	2,560
27	75.1	68.8	3,883	2,816
52	73.8	69.3	1,697	1,212
53	67.9	59.8	1,852	1,206
57	70.4	62.8	3,582	2,438
Average	71.4	65.6	2,905	2,046
Average per 100-pound deer per day	----	--	5,958	4,193

Alfalfa hay feeding resulted in remarkably uniform results, even though black-tailed deer reared in captivity, wild mule deer directly from the winter range, and wild mule deer from a previous diet of 100 percent bitterbrush were used.

Two and seven-tenths pounds of dry matter were eaten per 100-pound deer per day and this resulted in only a slight weight loss. The two black-tailed deer which were raised in captivity on alfalfa and barley, did not significantly change their weight. The three wild mule deer all lost weight slightly, which may indicate a degree of intolerance to a large intake of alfalfa hay alone.

An attempt was made to conduct digestion trials on meadow hay and oat hay. No deer, domesticated or wild, would eat more than 50 grams of these feeds a day, even though starving.

DISCUSSION

The nutrition of deer poses the same problems as those dealing with other ruminants. First the crude plant materials are stored in the rumen (paunch) and reticulum, where an extensive breakdown of crude protein, crude fiber, and complex carbohydrates occurs through fermentation by certain anaerobic organisms. True proteins, amino acids, sugars, starches, and related compounds are thus formed; these pass on into the remaining digestive organs of the deer to serve as sources of direct energy, maintenance, and growth for the animal. Considerable amounts of gases are formed by the fermentation, chiefly methane and carbon dioxide, plus volatile fatty acids and other gases in minor amounts.

This rumen fermentation produces a considerable quantity of heat which is independent of the deer's own metabolism, and which must be considered among other losses when determining energy available to the deer. This heat of fermentation may be exceedingly important to the deer in maintaining its body heat during cold weather, but otherwise represents a waste amount of heat energy. The gases of fermentation which are lost in a great measure by belching also represent a loss of potential heat energy which should be subtracted from the amount of digestible calories.

The daily calories (cal.) digested per hundred-weight (cwt.) of deer were about 4,500. The basal metabolism in cal./24 hours of a 100-pound mature animal is calculated as follows: Cal./day equals 39.5 x pounds $^{0.73}$ (Brody, 1945). This means a 100-pound deer would require 1,140 calories per day to just maintain itself in a resting, fasting condition in a thermo-neutral environment.

Hence, about 3,360 calories of digested energy go into (a) energy lost through gases found in rumen fermentation, (b) weight gain, and (c) demands for energy caused by moving about in cage, etc.

The methane energy production of cattle represents about nine percent of the gross feed energy. The carbon dioxide present after 24 hours is equal in volume to the methane. Methane has an energy equivalent of 9.5 cal./liter and CO_2 an energy equivalent of 4.0 cal./liter. The average gross intake of energy from the alfalfa grain and the alfalfa experiments was 5,372 calories. Therefore, the fermentation losses may be computed to a total of 688 calories, if it is allowable to transpose cattle data to deer. However, since the fermentation loss may be compensated for by the greater digestibility associated with the fermentation process (Brody, 1945), this may not be a real loss.

Table 22 summarizes the digestibilities obtained from the experiments, and compares the digestibilities with other investigators' results.

TABLE 22

Summary of Digestibilities
(Dry Weight Basis)

	Percentage coefficient of digestion of protein		Percentage total digestible nutrients	
	Morrison	Calculated	Morrison	Calculated
Alfalfa hay	78.5	71.4	55.6	65.6
Oats	86.5	80.9	77.7	86.2
Barley	88.4	71.8	86.9	81.4
Live oak	----	32.8	----	31.4
Chamise	----	negative	----	58.8
Bitterbrush	[1]35.7	56.8	[1]45.4	54.8
Sagebrush	[2]66.6	41.6	----	55.9

Morrison's values are based on determinations made with domestic stock. Smith's values were obtained using mule deer.
[1] Smith (1952).
[2] Smith (1950).

The calculated digestibilities of oats and barley were arrived at by subtracting the digestibilities of alfalfa hay from those of the alfalfa-grain mixtures. Seventy-one and four-tenths percent coefficient of digestion of protein and 65.6 percent TDN were the figures used for alfalfa. This is the standard procedure for determining digestibilities of concentrates (Morrison, 1950).

These calculated values for the grains are approximate, since different deer and different alfalfa hay were used in the several experiments.

The alfalfa plus grain diets were quite palatable and no significant weight changes were found. The combinations were highly digestible and confirm the author's observations that deer can live on a diet of alfalfa hay and barley.

The very low intake of live oak and chamise, at a time when the plants were extremely succulent and apparently highly palatable, is puzzling. The dry matter intake averaged only 0.75 pound per cwt. per day, which is only about one-third the expected amount indicated by the alfalfa grain results. These browses appeared to be unpalatable when fed as the sole item of diet, and to be of low digestibility.

The deer used in the experiments just referred to were raised in captivity. In general, the animals were docile and did not appear to mind the small cages. Boredom appeared frequently, with the deer doing much slow pacing or pawing continually at the floor or sides.

Bitterbrush digestibility in November and December, the months of greatest use, appeared to be slightly lower than the digestibility in March—a time when deer ordinarily are eating a larger amount of sagebrush. The value for bitterbrush protein digestibility (56.8 percent) appears to be definitely higher than the 35.7 percent reported by Smith (see Table 22). These values may be compared with our value of 71 percent for alfalfa hay. Our TDN of 54.8 percent for bitterbrush was about the same as Morrison's TDN of 55.6 percent for alfalfa hay and less than our TDN of 65.6 percent for alfalfa hay. The studies indicate that bitterbrush is a food which of itself will support deer with only a slight loss of weight for several weeks; it appeared as an extremely palatable food.

Sagebrush proved to be an exceedingly poor food, in that no deer would eat much of it willingly. Very pronounced weight losses occurred, and the digestibilities are in error to the extent that they represent animals on less than a maintenance diet, with perhaps an abnormally high content of nitrogen from tissue breakdown present in the feces. The total digestible nutrients in sagebrush (55.9 percent) are comparable to Morrison's alfalfa TDN of 55.6 percent. Smith did not report percentage of TDN. Our coefficient of digestion of sagebrush protein is 41.6 percent, which is considerably lower than Smith's figure of 66.6 percent for sagebrush.

Alfalfa hay was exceptionally palatable to domesticated black-tailed deer and somewhat less so to wild mule deer. All had a very similar coefficient of digestion for protein and TDN and there was no evidence that sudden shifts of diet had an adverse effect on the deer. However, the wild deer appeared to lose slightly on the diet. The mule deer ate only 709 grams cwt./day, contrasted with 1,999 grams/cwt./day consumed by domesticated blacktails.

The experiments were designed as digestion trials and not as feeding trials. The evidence indicates that alfalfa hay is a palatable and digestible feed for deer, supplying considerable digestible energy. However, it may well be that when wild deer feed on alfalfa hay alone for a month or more they may lose weight continuously and thus decline to a poor condition, as reported by Doman and Rasmussen (1944). The experiments indicate that alfalfa hay is a cheap but bulky source of easily digested energy.

No digestive upsets of any nature were observed during the studies, irrespective of the diet fed and including the periods following sudden switches from one diet to another. A possible exception is deer No. 326, which had a case of extremely liquid diarrhea on sagebrush experiment No. 33. This diarrhea cleared up 24 hours after a switch to alfalfa was made.

No craving for salt was apparent, as indicated by the indifferent attitude of the deer toward salt placed in their cages after they had been deprived of salt for 30 to 80 days.

Bitterbrush and alfalfa hay, although eaten by wild deer, failed to maintain the animals' weight. Bitterbrush actually supplied 548 grams of TDN per cwt. per day, as opposed to 476 grams of TDN per cwt. per day from alfalfa. The weight losses per day were nearly identical, which leads one to suspect a greater energy loss from fermentation in the case of the bitterbrush.

From Table 23 it appears that (1) around 800 grams of TDN per cwt./day are needed to maintain an animal's weight, (2) 476 to 548 grams of TDN per cwt. per day will result in a gradual loss of weight of 0.25 pound/day, and (3) 59 to 152 grams of TDN per cwt. per day will result in a rapid weight loss of 0.5 to 1.0 pound/day.[2]

TABLE 23

Intake of TDN and Weight Change Per Day

Diet	Grams TDN/cwt. per day	Pounds weight loss per day
Alfalfa	476	0.25
Bitterbrush	548	0.26
Sagebrush	152	0.87
Live oak	71	0.50
Live oak and chamise	59	1.0
Alfalfa + barley	801	none
Alfalfa + oats	881	none

Carbohydrates furnish energy. Proteins furnish both energy and materials for growth and maintenance. If carbohydrates alone are fed, the body stores protein, loses nitrogen at a very slow rate, and gets most of its energy requirements from the carbohydrates through their "protein sparing" action. Thus, in times of limited caloric intake carbohydrates rather than protein should be fed (Swift and French, 1954). Maintenance of weight is of relatively little importance over short periods.

In the case of a ruminant enough protein or nitrogen must be ingested to enable the rumen microorganisms to multiply and carry through the fermentation processes. In the course of our studies wild deer did at least as well on alfalfa as on bitterbrush alone, and certainly better than on sagebrush alone. This indicates that alfalfa theoretically can serve as a supplemental food equal in value to the best bitterbrush. However, since it appears that limited intake of di-

[2] Many weighings of deer have indicated that the weight of a deer may vary three pounds from day to day. An 80-pound deer voids about 1,500 to 2,000 cc. of urine per day, usually in the amount of 250 cc. at a time. Food and water may be taken sporadically; therefore, the weight of the deer can vary depending upon time of food and water intake and urine excretion.

gestible calories is probably the reason for deer deaths in times of stress, it follows that a supplemental feed should be concentrated, high in TDN, palatable, and nonspoiling. A 1:4 pelleted mixture of alfalfa hay and barley appears to be theoretically adequate.

No reason is apparent why a proposed supplement should be high in protein or laced with minerals, vitamins, etc. Nothing here need be said of the economics of feeding nor of the wisdom of indiscriminate use of supplemental feeding in efforts to maintain herd numbers greater than the natural forage will support.

SUMMARY

1. Digestion trials were conducted on deer, using alfalfa hay and oats, alfalfa hay and barley, live oak, chamise, bitterbrush, sagebrush and alfalfa hay.

2. Cages which allowed quantative control of feed and collection of feces uncontaminated by urine were designed and built.

3. The coefficients of digestion of protein were as follows: alfalfa hay plus oats 79.4 percent, alfalfa hay plus barley 71.8 percent, live oak 33.3 percent, chamise negative, bitterbrush 56.8 percent, sagebrush 41.6 percent, alfalfa hay 71.4 percent.

4. The total digestible nutrients were as follows: alfalfa hay plus oats 83.0 percent, alfalfa hay plus barley 78.9 percent, live oak 20.8 percent, chamise 58.8 percent, bitterbrush 54.8 percent, sagebrush 55.9 percent, alfalfa hay 65.6 percent.

5. Alfalfa plus oats and the alfalfa plus barley diets were relished by the deer and efficiently utilized. Bitterbrush and alfalfa hay, although relished, were utilized less efficiently and there was a definite weight loss on the diet.

6. Sagebrush, live oak, and chamise were not consumed in sufficient quantities to supply minimum energy requirements. In addition, their protein digestibility was low.

7. No significant differences in digestibilities of alfalfa hay by black-tailed deer raised in captivity or mule deer trapped from their natural winter range were found. However, there was a significant difference in intake per cwt. of deer between the two groups. There was an average intake of 1,999 grams per cwt. per deer per day for the two black-tailed deer, and an average intake of 709 grams per cwt. of deer per day for the three mule deer.

8. A 100-pound deer digests about 4,500 calories per day, even though the maintenance amount for a resting, fasting animal is only about 1,140 calories per day. Hence, about 3,360 calories per day go into energy of growth, movement, and production of rumen gases by fermentation. These figures apply to deer confined in a sheltered small space at temperatures not less than zero degrees F.

9. Water intake for all diets averaged 5.1 pounds per cwt. per day for all diets. The range was from 2.7 to 8.2 pounds per cwt. per day. The amount consumed is not necessarily correlated with the dryness of the food.

10. The findings give preliminary indications that single item diets are of limited value to deer, and that deer eat one species of plant only under special circumstances, and then not for prolonged periods.

11. No digestive upsets occurred when diets were suddenly shifted.

12. No craving for salt was displayed during the periods of the digestion trials.

13. On the basis of these experiments it can be said that all of the diets of natural vegetation which were studied contain a potentially adequate source of digestible energy. However, it appears that bitterbrush is the only plant studied which may be eaten as a sole item of diet for prolonged periods. The other plants are consumed in a much lesser amount, apparently because of low palatability. It appears that a deer herd environment should be managed so as to maintain a variety of palatable browse species, rather than one or a few species only.

14. Emergency feeding calls for a palatable feed containing a high TDN, concentrated and nonspoiling. No reason is apparent why an emergency feed should contain added vitamins, minerals, or large amounts of protein.

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EXPLORATORY OCEANOGRAPHIC OBSERVATIONS IN THE EASTERN TROPICAL PACIFIC, JANUARY TO MARCH, 1953[1]

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Experimental fishing with Japanese "longline" gear by the Pacific Oceanic Fishery Investigations of the United States Fish and Wildlife Service has demonstrated the presence of deep-living yellowfin and bigeye tuna in the central equatorial Pacific (Murphy and Shomura, 1952). An imaginative oceanographic program carried on in conjunction with the experimental fishing has led to a reasonable oceanographic interpretation of the observed distribution of tuna (Cromwell, 1953).

Since nothing was known about the distribution of such deep-living tuna in the eastern equatorial Pacific, an exploratory expedition was sent out aboard the M. V. N. B. SCOFIELD from January 23 to March 18, 1953, under the joint sponsorship of the California Department of Fish and Game, the Inter-American Tropical Tuna Commission, and the Scripps Institution of Oceanography of the University of California. Biological results of this expedition were described by Wilson and Shimada (1955). In addition to the experimental fishing and the biological program, a limited oceanographic program was carried out. The purpose of this paper is to discuss the oceanographic results of this expedition.

OCEANOGRAPHIC OBSERVATIONS

The track of the M. V. N. B. SCOFIELD is shown in Figure 1. Due to failure of the bathythermograph winch, bathythermograph observations (to 900 feet) were made only at the 26 stations where experimental fishing was carried on. In addition, numerous observations of surface temperature (bucket thermometer) and surface salinity (Knudsen titration) were made. Figures 2 and 3 show the locations of these observations. At all stations except Nos. 25 and 26, surface samples were collected and frozen for subsequent analysis for dissolved inorganic phosphate-phosphorus and silicate-silicon. These analyses were made at the Scripps Institution by Mr. Robert Holmes, using standard absorptiometric methods.

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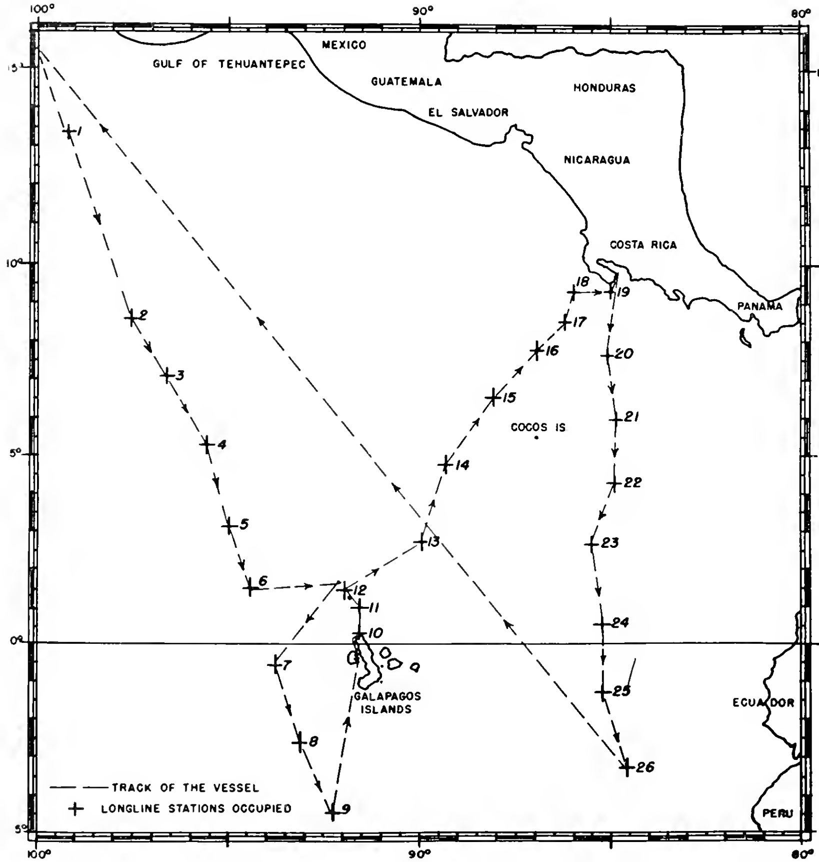

FIGURE 1. Track of M.V. *N. B. Scofield*, January 23 to March 18, 1953, showing location of experimental fishing stations.

In addition, current measurements were made, using towed electrodes (Von Arx, 1950) and a confined current drag from the drifting ship (Vine, Knauss, and Volkmann, 1954). Interpretation of the results of these measurements awaits completion of a theoretical treatment of such data now under way, and will be discussed in a subsequent paper.

DISTRIBUTION OF TEMPERATURE AND SALINITY

The horizontal distribution of surface temperature is shown in Figure 2 and of surface salinity in Figure 3. The distribution of temperature is also shown in bathythermograph sections, Figures 4, 5, and 6.

It was not considered advisable to attempt to contour surface distributions because of the spacing of observations, and because changes

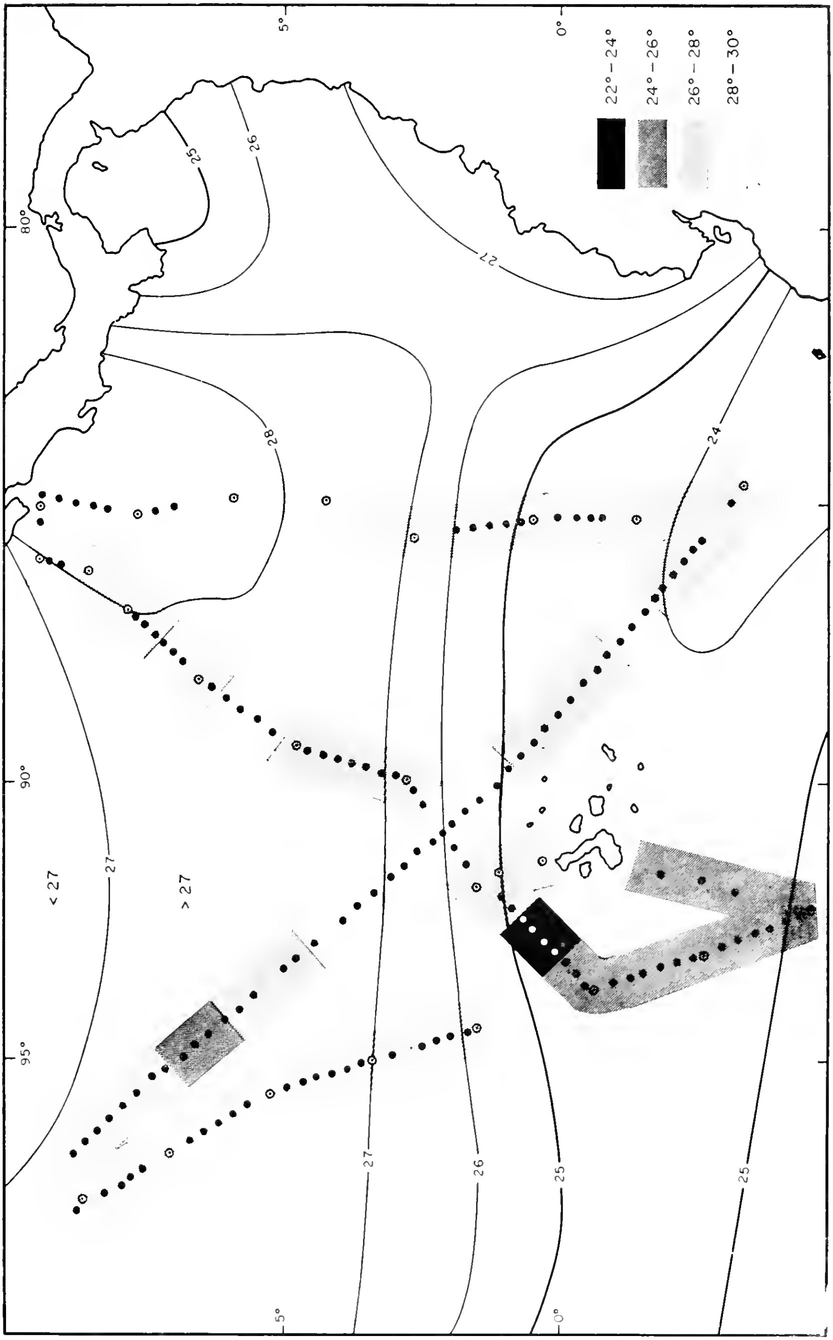

FIGURE 2. Distribution of surface temperatures (Centrigrade) along track. Isotherms are February average surface temperatures, from Schott (1935).

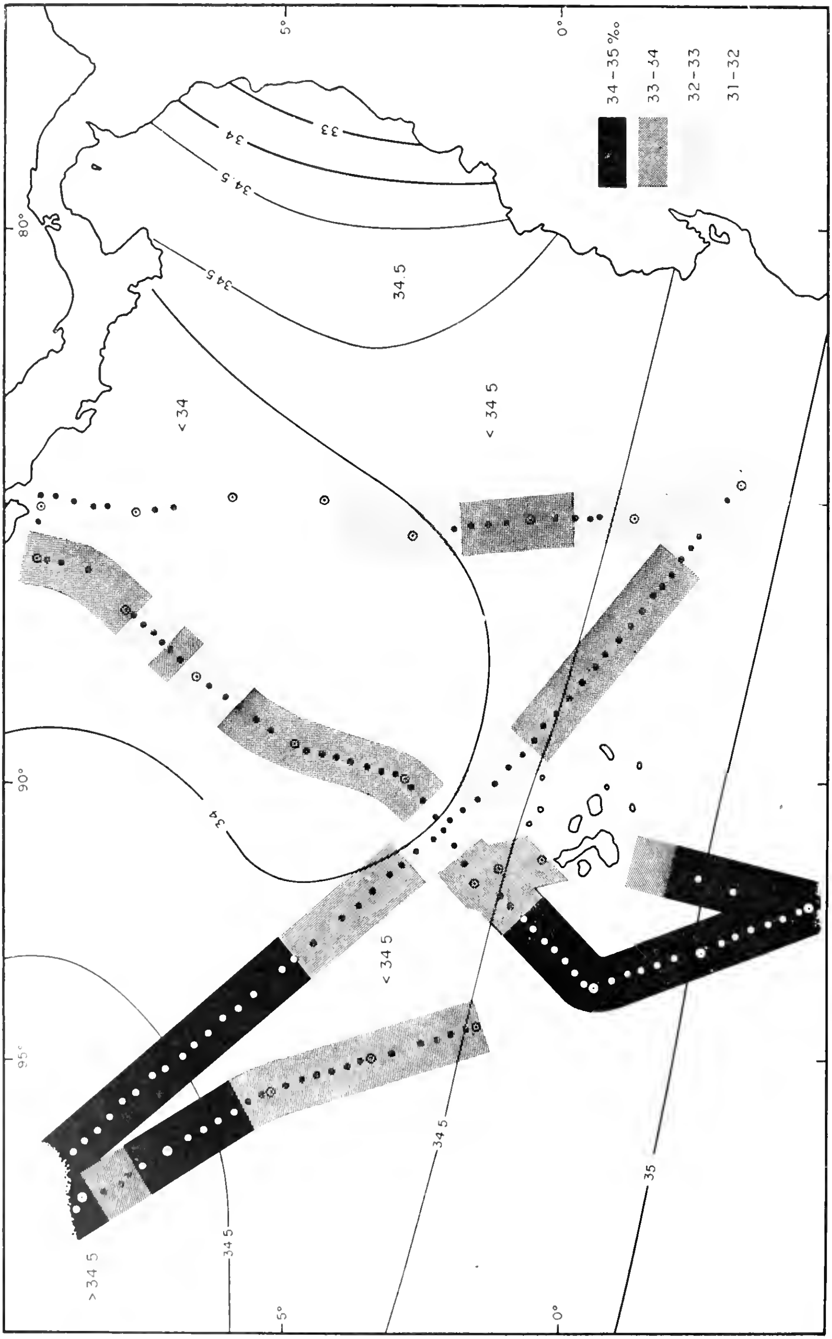

FIGURE 3. Distribution of surface salinity along track. Isohalines are Northern Hemisphere winter average surface salinities, from Schott (1935).

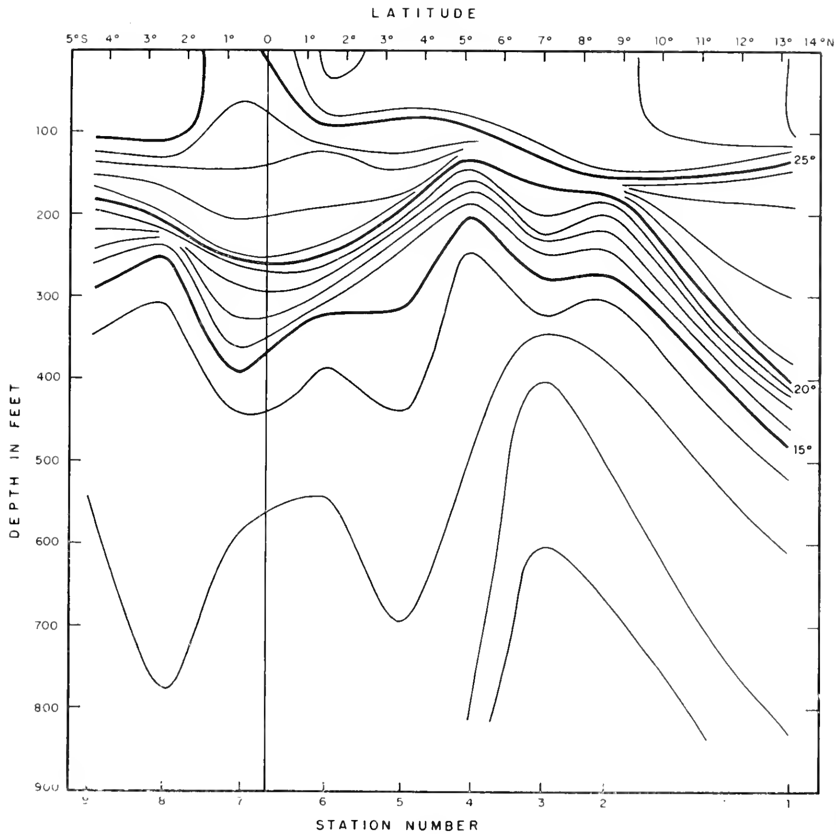

FIGURE 4. Temperature-depth section from westernmost bathythermograph profile.

in surface conditions during the cruise made it impossible to treat the data as simultaneous. Therefore, a system of shading was used to show variations in surface concentration along the track of the ship. The isopleths drawn on Figures 2 and 3 were taken from Schott (1935) and are intended to represent average surface temperatures in the month of February (Figure 2) and average surface salinity during Northern Hemisphere winter (Figure 3).

Examination of Figure 2 reveals a distribution of temperature on the westernmost line similar to average conditions. In particular, the relatively cold water found at the equator and south of the equator is consistent with the usual westward extension of cold water from the Peru Current which feeds the South Equatorial Current, and with upwelling at the equator due to wind-induced divergence (Yoshida, Mao, and Horrer, 1953; Cromwell, 1953). The coldest temperature observed, 23.5 degrees C., was located at zero degrees 30 minutes north latitude.

On the easternmost line, surface temperatures are strikingly different from the average values. Surface water with a temperature of greater than 28 degrees C. was found farther south and west than usual, and

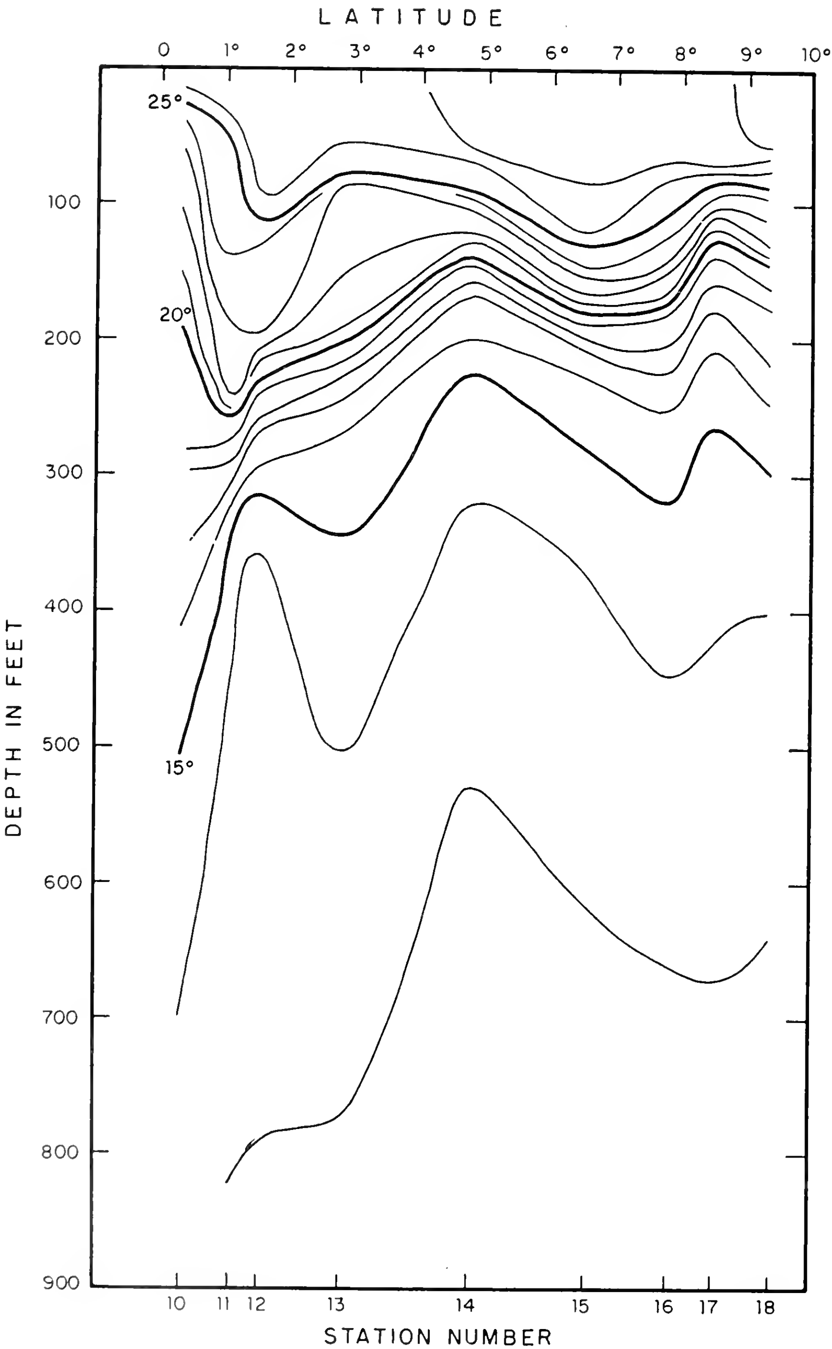

FIGURE 5. Temperature-depth section from central bathythermograph profile.

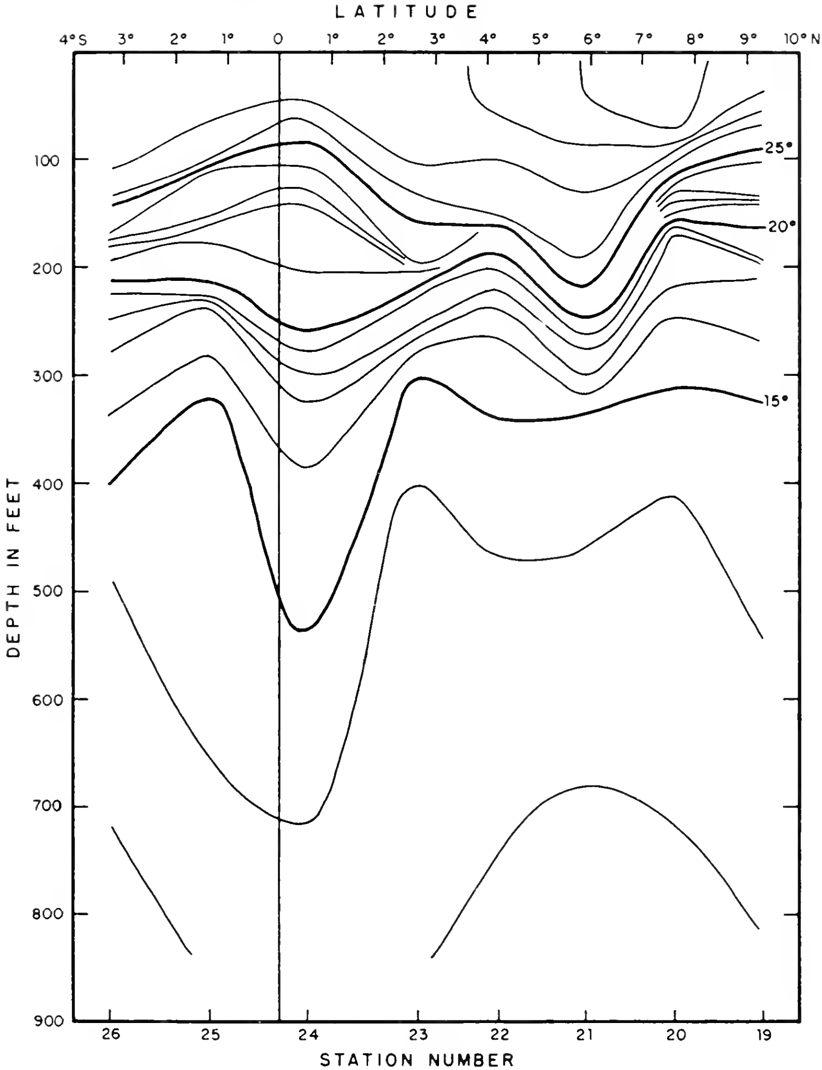

FIGURE 6. Temperature-depth section from easternmost bathythermograph profile.

in the region between Ecuador and the Galapagos Islands where February surface temperatures are usually less than 25 degrees C., values of 26 degrees to greater than 28 degrees C. were observed. Evidence of a rapid change in surface conditions is found in the region north of the Galapagos Islands, where an early line was recrossed less than three weeks later. On the later crossing, surface temperatures in the area were found to be 2 degrees C. higher than those previously observed. For example, on February 16, at 2° 07′ N., 90° 54′ W., the surface temperature was 26.4 degrees C.; on March 7, at 2° 00′ N., 90° 44′ W., the surface temperature was 28.4 degrees C.

Examination of the westernmost bathythermograph section (Figure 4) confirms the presence of upwelling at the equator, apparently from a depth no greater than 50 meters, in contrast with the central equatorial Pacific, where Cromwell's diagrams suggest that upwelling may be effective to depths as great as 100-150 meters. Unpublished observations from Scripps Institution's "Shellback" expedition, May to August, 1952 (Wooster, 1952) also show equatorial upwelling in the eastern equatorial Pacific to be effective to a lesser depth than in the central equatorial Pacific. However, since the depth of the thermocline in the equatorial region decreases from west to east (Sverdrup, Johnson, and Fleming, 1942; p. 708), shallow upwelling in the east may well be effective in supplying the photic zone with nutrients.

A trough in isotherms at the equator, below the depth of influence of upwelling, can be seen in Figure 4. This feature is also apparent in Cromwell's meridional sections and is probably related to the Equatorial Undercurrent, recently discovered through direct measurements of subsurface currents at the equator (Cromwell, Montgomery, and Stroup, 1954).

Conclusions concerning zonal flow can be reached from a meridional bathythermograph section only if the geostrophic approximation is valid, if the observations are sufficiently deep to reach a suitable reference surface, and if the relation between temperature and salinity is known (LaFond, 1949). Although the available observations do not entirely satisfy these restrictions, they are consistent with a westward North Equatorial Current north of 5° N. and with an eastward Equatorial Countercurrent south of 5° N. The southward extent of the countercurrent is indeterminate because of the failure of the geostrophic approximation in the vicinity of the equator.

The southern end of the central section (Figure 5) is complicated by the proximity of the southernmost station (Station 10) both to the equator and to the northern tip of Isabela Island, the largest of the Galápagos group. The Equatorial Countercurrent again appears to be present south of 5° N.; to the north the nature of the zonal flow is not obvious.

The easternmost section (Figure 6) shows no clear evidence of equatorial upwelling at the surface (see also Figure 2), water warmer than 27 degrees C. extending across the equator to the southernmost station, at 3° 16′ S. Below the surface a crest in isotherms can be seen, and deeper still the trough believed to be associated with the Equatorial Undercurrent.

Examination of the distribution of surface salinity (Figure 3) shows conditions to be most nearly average on the westernmost line, although values north of the equator seem to be several tenths per mille too low. The highest value, 34.74 ‰ was found at 0° 42′ N. On the easternmost line conditions differ strikingly from average, with values of 31-32 ‰ in the north (where average values are 33.5-34 ‰) and values of 32-33 ‰ in the south (where average values are 34.5-35 ‰). In the region north of the Galápagos Islands where lines cross, the salinity decreased markedly during the three-week interval. Thus on February 16, at 2° 07′ N., 90° 54′ W., surface salinity was 33.34 ‰; on March 7, at 2° 00′ N., 90° 44′ W., surface salinity was 32.28 ‰.

DISCUSSION

The available observations are obviously inadequate, both in kind and in spatial coverage, for a clear understanding of the oceanography of the region. For example, it is not possible to draw adequate surface or subsurface horizontal distributions or to make velocity or transport computations. However, despite the limitations of the data, certain oceanographic features are clearly evident.

The equatorial divergence is a well-known phenomenon in the Pacific (Sverdrup, Johnson, and Fleming, 1942; p. 711). The presence during this cruise of equatorial upwelling in the westernmost section is apparent from examination of Figures 2, 3 and 4. It is confirmed by the results of phosphate and silicate analyses. An examination of Table 1 shows that the highest surface concentrations of phosphate were found at Stations 7 and 10, the two stations closest to the equator west of 90° W. (Relatively high values were also found at Stations 8 and 9, south of the equator in the South Equatorial Current; significantly lower concentrations were measured at all other stations). Concentrations of surface silicate were so low at all stations as to be at the extreme limit of sensitivity of the analytical method used, and hence are not tabulated here. However, the two highest values were again found at Stations 7 and 10.

Since data from the westernmost section seem to agree with average conditions, it is of interest to compare the relationship between oceanographic conditions and biological activity with that found in the central equatorial Pacific. Investigators there (King and Demond, 1953) report the greatest abundance of zooplankton in the region of the equator, the rich zone extending from about 6° N. to 5° S. latitude. Frequently, but not always, the zooplankton maximum occurred at or very near the site of upwelling. A statistically significant positive correlation was found between zooplankton volume and surface inorganic phosphate. Although, paradoxically, Wilson and Shimada (1955; Table 2) report the lowest plankton catches at the two stations with the highest surface phosphate concentrations, in general the same zone has a high standing crop of zooplankton. The catch of tuna in the eastern tropical Pacific (Wilson and Shimada, 1955; Table 1) shows peaks of over six tuna per 100 hooks at Stations 5 (3°06′N.) and 9 (4°28′S.), with good catches in between, and resembles, both in quantity and in meridional variation, certain of the central equatorial Pacific fishing sections (Murphy and Shomura, 1953). Thus, in general the relation between oceanographic conditions and biological activity is similar in the two areas.

The absence of surface indications of equatorial upwelling in the easternmost section is shown by Figures 2, 3 and 6. In addition, neither the surface phosphate nor the surface silicate concentrations were significantly higher at Station 24 than at the stations to the north. Unpublished data from the "Shellback" expedition, which established a series of oceanographic stations along 85° W. from 15° S. to 10° N. in July, 1952, also show no signs of upwelling at the equator. It is not surprising that sections across the equator within 300 miles of the eastern border of the Pacific do not show the usual picture of equatorial circulation found in the open ocean. The distribution of properties

TABLE 1

Surface Phosphate-phosphorus Concentrations, in Microgram Atoms Per Liter of PO_4-P, in Samples Collected by M.V. N. B. SCOFIELD, January to March, 1953

Station No.	Location	PO_4–P	Station No.	Location	PO_4–P
1	13° 18′ N.-99° 07′ W.	0.36	13	2° 47′ N.-89° 57′ W.	0.38
2	8° 35′ N.-97° 32′ W.	0.42	14	4° 46′ N.-89° 20′ W.	0.39
3	7° 09′ N.-96° 39′ W.	0.46	15	6° 32′ N.-88° 08′ W.	0.37
4	5° 12′ N.-95° 36′ W.	0.37	16	7° 48′ N.-86° 56′ W.	0.35
5	3° 06′ N.-95° 00′ W.	0.38	17	8° 29′ N.-86° 12′ W.	0.34
6	1° 30′ N.-94° 25′ W.	0.32	18	9° 22′ N.-86° 01′ W.	0.36
7	0° 36′ S.-93° 44′ W.	0.68	19	9° 20′ N.-85° 00′ W.	0.36
8	2° 36′ S.-93° 05′ W.	0.63	20	7° 36′ N.-85° 09′ W.	0.29
9	4° 28′ S.-92° 16′ W.	0.51	21	5° 54′ N.-84° 52′ W.	0.29
10	0° 20′ N.-91° 23′ W.	0.81	22	4° 14′ N.-84° 55′ W.	0.31
11	1° 06′ N.-91° 35′ W.	0.39	23	2° 40′ N.-85° 33′ W.	0.34
12	1° 32′ N.-91° 50′ W.	0.39	24	0° 32′ N.-85° 16′ W.	0.38

in this region is dominated by the proximity of the northern boundary of the Peru Current to the equator and by the effect of changes in local winds from season to season and from year to year on the location of this boundary and on the circulation north of the boundary.

There is ample evidence that 1953 was an unusual year in the eastern tropical Pacific. The presence of warm, low saline water between the Galápagos Islands and Ecuador is undoubtedly related to the displacement of the Equatorial Countercurrent southward along the coast of northern Peru, reported by Schweigger (1953). Surface temperatures of 28 degrees C. were observed as far south as Talara, Peru, in March, and animals whose normal habitat is northwest of Cabo Blanco, Peru, were found as far south as 11 degrees S. Between March 10th and May 25th, the 1953 Yale Expedition made oceanographic observations along the coast of Peru (Posner, 1954). Surface temperatures greater than 28 degrees C. and salinities as low as 32 per mille were observed. The invasion of warm water was accompanied by northerly winds, and a southward current was found as far south as Aguja Point (6° S.).

The large scale displacement of the Equatorial Countercurrent southward along the coast of Peru from December to April is commonly referred to as "El Niño" (Schott, 1951). Schott attributes the phenomenon to a shift of the meteorological equator southward across the equator and the consequent replacement of the southeast trade winds with northerly winds. These northerlies at the same time cause upwelling of cold and saline waters in the Gulf of Panama. To some extent this is an annual occurrence and only rarely is so pronounced as to affect conditions south of the Gulf of Guayaquil.

An interesting feature of the SCOFIELD observations is the center of warm water of low salinity located off the coast of Central America, south of Puntarenas, Costa Rica. This condition could be produced by warming *in situ* and by excess of precipitation over evaporation (Jacobs, 1951) during a period of several months or more of relative stagnation. Flow of these waters southward is suggested by the increase of temperature (2 degrees C.) and the decrease of salinity (one per mille) during a period of less than three weeks in the region north of the Galápagos Islands. Apparently displacement of the Equatorial

Countercurrent was accompanied by a wind-induced drift of surface water from the north, and the water found south of the equator between the Galápagos Islands and Ecuador was Equatorial Countercurrent water either modified by mixing with warm water of low salinity from the north, or overlain by such water. Schott (1931) in a study of the disastrous "El Niño" of 1891, compared meteorological conditions during the event with those of other seasons and other years. A clearer understanding of the origin and nature of the 1953 "El Niño" would result from a study of the more extensive historical weather records now available from this area, comparing 1953 records with those of other years.

SUMMARY

Oceanographic results of an experimental fishing expedition to the eastern tropical Pacific early in 1953 are discussed. Along a line at approximately 95 degrees W., both biological and other oceanographic observations resembled those previously described in the central equatorial Pacific. Between the Galápagos Islands and Ecuador the presence of unusual surface conditions (high temperature and low salinity) is related to the occurrence of "El Niño" observed along the coast of Peru.

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TUNA LONGLINING: RESULTS OF A CRUISE TO THE EASTERN TROPICAL PACIFIC OCEAN[1]

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INTRODUCTION

The commercial longline fishing activities of the Japanese in the western Pacific Ocean, and more recently, the equatorial tuna explorations of the Pacific Oceanic Fishery Investigations, United States Fish and Wildlife Service, in the central Pacific region have demonstrated the presence in these areas of deep-living yellowfin tuna (*Neothunnus macropterus* Temminck and Schlegel) and bigeye tuna (*Parathunnus sibi* Temminck and Schlegel) of larger sizes than normally taken at the surface. In waters adjacent to the equator this subsurface distribution of large tunas has been found to exist eastward to 120 degrees west longitude, which is about 1,700 miles west of the presently flourishing eastern Pacific surface tuna fishery. These developments give rise to the question of whether or not there may be present in the region of the latter fishery similar, if not part of the same, stocks of tunas, living at depths which make them unavailable to present live-bait and purse-seine fishing methods. The existence of such deep-living stocks of adult fish bears important implications to the future welfare of the eastern Pacific fishery for tropical tunas.

In order to obtain first-hand information relating to this problem, and at the same time, to learn more about the general oceanic conditions of the region as it may affect the tunas, an expedition sponsored by the California Department of Fish and Game, the Inter-American Tropical Tuna Commission, and the Scripps Institution of Oceanography was conducted from January 23, 1953, to March 18, 1953. The United States Fish and Wildlife Service also participated by providing technical assistance and the loan of certain items of essential gear.

This report summarizes the results of longline fishing and some of the biological findings of the cruise (53-S-1). Evidence is presented to support the belief that in the eastern tropical Pacific region there are large tunas inhabiting depths well below the surface, whose distribution appears to be influenced by features of the oceanic circulation rather than by the presence of land masses.

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[2] Now with U. S. Fish and Wildlife Service, Boston, Mass.

ITINERARY

The California Department of Fish and Game survey vessel, N. B. Scofield, departed from Los Angeles Harbor on January 23, 1953, and the first station was occupied eight days later, on January 31 (Figure 1). After working southward across the equator and completing Station No. 9 at 4 degrees 28 minutes south latitude on February 10, the Scofield put in at the Galápagos Islands, to prepare

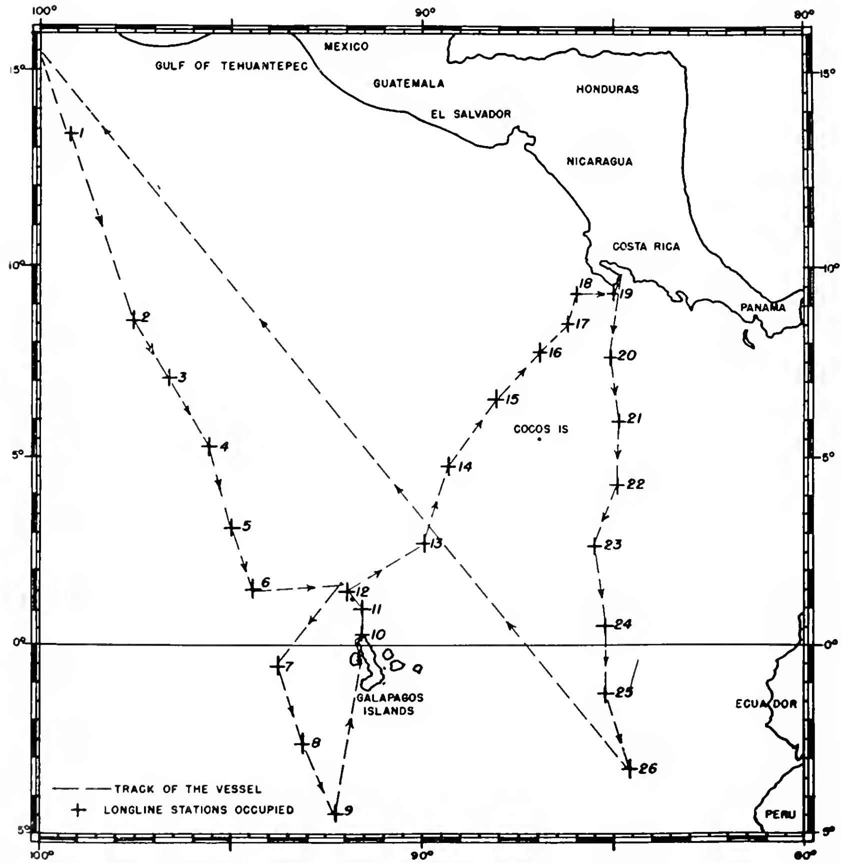

FIGURE 1. M.V. *N. B. Scofield* Cruise 53-S-1, January 23-March 18, 1953.

for the second leg of the cruise. The second leg, a northeasterly track from the Galápagos Islands to the Central American mainland, was begun on February 13. The last station of this leg was completed on February 22, and the vessel entered Puntarenas, Costa Rica, for fuel and provisions. The third and last leg of the cruise was begun on February 26, and the vessel completed the last station off the coast of Ecuador on March 4. The expedition was completed by the arrival of the Scofield in Los Angeles Harbor on March 18.

RESULTS

Longline Fishing

Japanese-style longlines are the only practicable means now known of catching tunas which might be found at below-surface levels in the ocean. For this reason, longlines identical in design and dimension with those used successfully by the Pacific Oceanic Fishery Investigations in their exploratory studies were obtained and employed by the expedition (Figure 2; for a detailed description of these longlines, see: Niska (1953)).

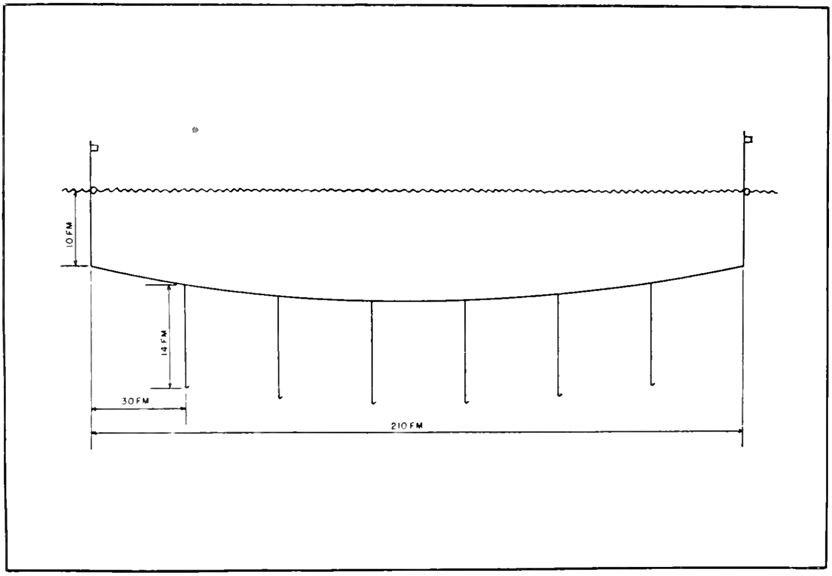

FIGURE 2. One basket; langline gear used by M.V. *N. B. Scofield*, Cruise 53-S-1.

Fishing operations were generally conducted under ideal weather and sea conditions, and it was usually possible to set about 50 six-hook baskets at each station. Most of the gear was set baited with large sardines, obtained and preserved aboard the vessel in a frozen condition, but in some instances the hooks were baited partly with sardines and partly with squid. Both kinds of bait seemed to be equally effective.

At all stations the longlines were laid just after daybreak. Average elapsed time in setting 50 baskets was approximately one hour at a vessel speed of about seven knots. The gear was allowed to "soak" for about six hours before it was brought in. The retrieving operation presented no serious difficulties except in areas of strong current shear, such as around the Galápagos Islands, where the longlines were badly tangled. A high-speed longline hauler of Japanese manufacture was used in retrieving the lines, and the average time required for hauling in a set of 50 baskets was three hours.

A total of 1,180 baskets (7,080 hooks) was fished during the course of the expedition for an average of 45 baskets (270 hooks) per station. A breakdown of the total catch by species and other operational details is given in Table 1.

TABLE 1

M.V. N. B. SCOFIELD, Cruise 53-S-1

Station summary

Station no.	Date 1953	Position	No. baskets fished	Catch by species					Total no. fish
				Yellow-fin	Big-eye	Spear-fishes	Sharks	Others	
1	1-31	13° 20′ N.-99° 10′ W.	30	0	0	5	5	0	10
2	2-2	8° 35′ N.-97° 32′ W.	40	2	0	5	8	1	16
3	2-3	7° 02′ N.-96° 39′ W.	39	2	1	3	9	2	17
4	2-4	5° 12′ N.-95° 36′ W.	50	4	1	3	6	0	14
5	2-5	3° 06′ N.-95° 00′ W.	51	16	4	0	3	1	24
6	2-6	1° 30′ N.-94° 25′ W.	50	9	3	1	6	2	21
7	2-8	0° 36′ S.-93° 44′ W.	50	4	1	0	13	0	18
8	2-9	2° 36′ S.-93° 05′ W.	50	6	2	0	7	1	16
9	2-10	4° 28′ S.-92° 16′ W.	50	19	1	0	4	1	25
10	2-13	0° 15′ N.-91° 20′ W.	50	1	1	0	7	0	9
11	2-14	1° 10′ N.-91° 35′ W.	50	0	0	1	8	1	10
12	2-15	1° 32′ N.-91° 51′ W.	50	0	0	1	8	0	9
13	2-16	2° 47′ N.-89° 57′ W.	50	0	0	0	4	0	4
14	2-17	1° 46′ N.-89° 20′ W.	50	0	0	3	13	3	19
15	2-18	6° 32′ N.-88° 08′ W.	50	0	0	3	30	0	33
16	2-19	7° 18′ N.-86° 56′ W.	50	11	0	8	10	1	30
17	2-20	8° 29′ N.-86° 12′ W.	50	0	0	9	6	0	15
18	2-21	9° 22′ N.-86° 01′ W.	50	2	0	12	2	2	18
19	2-22	9° 20′ N.-85° 00′ W.	50	0	0	13	1	1	18
20	2-26	7° 36′ N.-85° 09′ W.	40	0	0	1	5	0	6
21	2-27	5° 54′ N.-84° 52′ W.	25	0	0	0	32	0	32
22	2-28	4° 14′ N.-84° 55′ W.	31	0	0	4	24	0	28
23	3-1	2° 40′ N.-85° 33′ W.	31	0	1	1	11	0	13
24	3-2	0° 32′ N.-85° 16′ W.	45	0	0	2	6	2	10
25	3-3	1° 18′ S.-85° 15′ W.	49	0	0	1	1	0	2
26	3-4	3° 16′ S.-84° 38′ W.	49	0	1	2	1	0	7
Totals			1,180	76	16	78	236	18	424

Tunas were caught at 11 of the 26 fishing stations. Fishing along the first leg of the station pattern, from Stations No. 1 to No. 9, accounted for 82 percent of all tunas captured by the longlines and this would appear to indicate that deep-swimming large tunas were more concentrated in outlying oceanic waters than in areas close to the American mainland. The most productive zone of tuna fishing was the region adjacent and transverse to the equatorial current system, west of the Galápagos Islands. The catch at stations between 5 degrees north latitude and 4 degees south latitude along the offshore line averaged 4.3 tuna for each 100 hooks fished per day. The best single stations were Nos. 5 and 9, where 6.7 tuna were caught for every 100 hooks fished. No surface signs of fish were observed in areas where these tuna were found to occur. Longline tuna fishing was unproductive on the remaining two legs of the cruise and, contrary to expecta-

tions, the expedition found extremely poor fishing in waters immediately around the Galápagos Islands, which is one of the most productive localities at present for surface tuna fishing.

The catch ratios for all stations by kind of fish were as follows:

Yellowfin tuna	1.1 fish per 100 hooks
Bigeye tuna	0.2
Spearfishes (marlins and sailfish)	1.1
Sharks	3.3
Other	0.3

Although the results of longline fishing may be used to interpret the probable distribution and apparent abundance of deep-dwelling tunas in the eastern tropical Pacific Ocean, it is difficult to assess the true significance of these data because of abnormal oceanic conditions which existed in the equatorial area at the time of the expedition. This anomalous condition, known as "El Niño", is treated in detail under results of oceanographic studies made by the expedition (Wooster and Jennings, 1955).

Tuna Biology

The bigeye and yellowfin tunas that were taken by the longlines were all uniformly large fish. Most of them measured over 1,400 mm. in total length and weighed over 200 pounds. The largest were the bigeye tuna and these weighed upwards of 300 pounds. Figure 3 shows the number of tunas caught and the size range of each species. For purposes of comparison, there is also included a length-frequency distribution of a

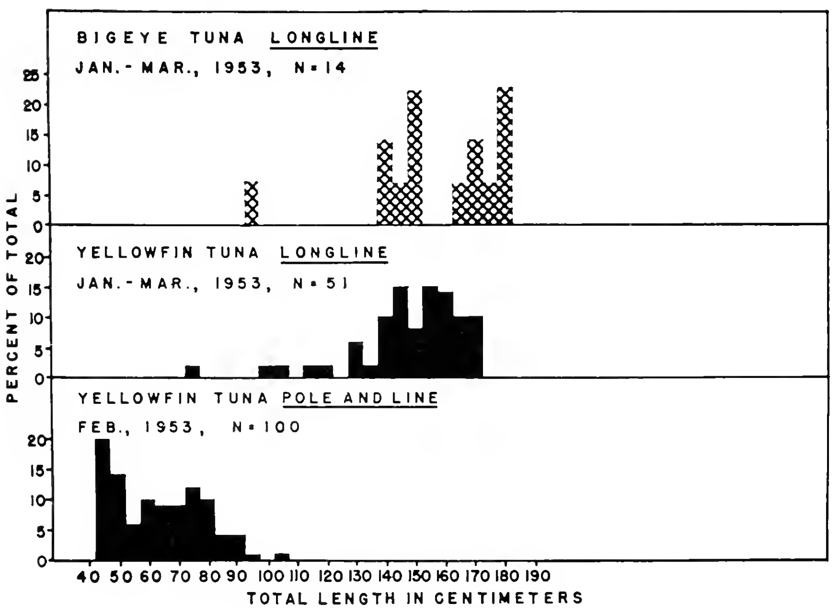

FIGURE 3. Length frequencies of some tropical eastern Pacific tunas.

sample of yellowfin tuna taken from the catch of a tuna clipper which was operating at about the same time and in the same region as the expedition. It is readily apparent that the longlines caught yellowfin tuna of much larger size than those which were taken by pole and line gear. A similar comparison for bigeye tuna is not possible because this species, although occasionally caught by clippers, is not segregated from the yellowfin at the ports of landing. It is believed, however, that in general for bigeye tuna an equal disparity between sizes is to be found for the different types of fishing gear as shown here for yellowfin tuna.

Several of the tunas of both species were examined internally for degree of sexual maturity. Most of the reproductive elements of these fishes, both male and female, were in an advanced ripening stage, and a few individuals possessed ripe gonads. These observations would seem to indicate the onset of a spawning season, and it is not improbable that some spawning takes place during the spring months and possibly at other times of the year in or near the region where these tunas were captured.

Stomachs from as many fish as possible were retained in order to determine their feeding habits. A report on this phase of the biological work is presented as a separate publication (Juhl, 1955).

In addition, samples for racial studies by means of blood typing and paper chromatography were obtained from most of the tunas.

Plankton

The Pacific Oceanic Fishery Investigations have found a meaningful relationship between the occurrence of tunas and the presence of plankton in their studies of the distribution and relative abundance of large tunas in the equatorial central Pacific (Murphy and Shomura, 1953). In order to provide a basis for examining the possibility of a similar correlation between tuna abundance and zooplankton abundance in the eastern Pacific, quantitative plankton hauls were made coincident with longline tuna fishing at each station. These collections were made during daylight hours with a one-meter conical net towed obliquely from a depth of 200 meters to the surface.

Plankton wet volumes were determined for these collections and the results are given in Table 2.

In general, the plankton volumes conform with values obtained previously by the Scripps Institution of Oceanography expedition "Shellback", which was active in the same general region of the eastern tropical Pacific from May to August, 1952. Wet volumes for the longline cruise, however, were higher, on the average, than those from "Shellback" due possibly to a seasonal effect, the two expeditions having been conducted at different times of the year. Collections at the four southernmost stations (Stations Nos. 23-26) on the inshore line from Costa Rica southward may also reflect transient variations in plankton abundance due to "El Niño" conditions. No correlation was apparent between plankton abundance and success of longline fishing.

TABLE 2

Eastern Tropical Pacific Plankton Wet Volumes Corrected to Wet Volumes in Cubic Centimeters Per 1,000 Cubic Meters of Sea Water Strained

Station no.	Position lat.-long.	Date 1953	Start (local time)	End (local time)	Depth meters	Vol. water strained c.m.	Vol. per 1,000 c.m. strained	
							total cc.	sm. org. cc.
1	13° 20′ N.-99° 10′ W.	1-31	0839	0903	127	1274	100	100
2	8° 35′ N.-97° 32′ W.	2-2	0809	0831	159	633	161	161
3	7° 02′ N-96° 39′ W.	2-3	0840	0855	182	751	93	93
4	5° 12′ N.-95° 36′ W.	2-4	0804	0825	190	733	175	175
5	3° 06′ N.-95° 00′ W.	2-5	0744	0806	199	696	85	85
6	1° 30′ N.-94° 25′ W.	2-6	0809	0831	183	725	119	119
7	0° 36′ S.-93° 44′ W.	2-8	0854	0915	196	677	72	49
8	2° 36′ S.-93° 05′ W.	2-9	0753	0815	203	666	114	114
9	4° 28′ S.-92° 16′ W.	2-10	0753	0816	191	671	167	92
10	0° 15′ N.-91° 20′ W.	2-13	0823	0846	219	685	70	70
11	1° 10′ N.-91° 35′ W.	2-14	0738	0801	208	647	117	117
12	1° 32′ N.-91° 51′ W.	2-15	0744	0816	213	661	159	159
13	2° 47′ N.-89° 57′ W.	2-16	0739	0801	203	674	119	119
14	4° 46′ N.-89° 20′ W.	2-17	1023	1046	200	649	142	139
15	6° 32′ N.-88° 08′ W.	2-18	0809	0830	204	698	97	97
16	7° 48′ N.-86° 56′ W.	2-19	0804	0826	205	713	102	102
17	8° 29′ N.-86° 12′ W.	2-20	0809	0831	229	620	85	85
18	9° 22′ N.-86° 01′ W.	2-21	0824	0846	213	676	99	99
19	9° 20′ N.-85° 00′ W.	2-22	0803	0825	203	696	72	72
20	7° 36′ N.-85° 09′ W.	2-26	0744	0805	202	700	96	86
21	5° 54′ N.-84° 52′ W.	2-27	0724	0746	211	682	145	145
22	4° 14′ N.-84° 55′ W.	2-28	0744	0806	191	739	100	100
23	2° 40′ N.-85° 33′ W.	3-1	0739	0801	229	626	110	110
24	0° 32′ N.-85° 16′ W.	3-2	0753	0815	219	667	147	147
25	1° 18′ S.-85° 15′ W.	3-3	0813	0835	205	710	121	121
26	3° 16′ S.-84° 30′ W.	3-4	0754	0815	201	663	202	202

ACKNOWLEDGMENTS

Acknowledgment is made of the fine cooperation received from the various field units of the United States Fish and Wildlife Service. In particular, we wish to recognize the assistance provided by the Pacific Oceanic Fishery Investigations and the services of their expert longline fisherman, Mr. Sam Okamura. We are also indebted to the South Pacific Fishery Investigations for their analyses of the collected plankton material.

Lastly, much credit for the success of the expedition must be given to the energetic captain and crew of the N. B. SCOFIELD.

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NOTES ON THE FEEDING HABITS OF SUBSURFACE YELLOWFIN AND BIGEYE TUNAS OF THE EASTERN TROPICAL PACIFIC OCEAN[1]

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INTRODUCTION

The joint longline fishing expedition of the California Department of Fish and Game, the Inter-American Tropical Tuna Commission, and the Scripps Institution of Oceanography in early 1953 was successful in establishing the presence of deep-living large tunas in the eastern tropical Pacific Ocean (Wilson and Shimada, 1955). Since the distribution of these tunas in time and space may well be related to the presence of a favorable food supply, an attempt was made by scientists of the expedition to collect material to elucidate the food and feeding habits of these fishes, of which little is now known. This report summarizes the results of studies of the stomach contents of some of the yellowfin tuna (*Neothunnus macropterus*) and bigeye tuna (*Parathunnus sibi*) which were caught by the longlines.

METHODS AND MATERIALS

In all, 10 stomachs of yellowfin tuna and 5 stomachs of bigeye tuna were preserved in formalin and brought back for study. These stomachs were opened and the contents of each carefully removed and placed in a conical graduate. A quantitative measure of the major categories of food present in each stomach was obtained by displacement. The contents were then sorted and specific identification made, wherever possible, of the organisms ingested by the different fish.

RESULTS

The details of the stomach content analyses, together with other pertinent data, are given in Table 1. The quantitative values, in particular, should be interpreted with discretion because of errors introduced by (1) continued digestion within the stomachs up to the time of their removal, (2) failure to remove entirely the stomach and its contents from the fish, and (3) the tendency for these fish to regurgitate their food upon capture. In spite of these sources of error and the small number of stomachs, it is, nevertheless, possible to obtain a fairly good idea of what these tunas had been feeding upon when they were caught.

[1] Submitted for publication October, 1954.

TABLE 1

Stomach Contents of Yellowfin and Bigeye Tunas From the Eastern Tropical Pacific Ocean

Species	Total length (mm.)	Place of capture Lat. Long.	Date 1953	Stomach contents		
				Displ. vol. (ml.)	Kind	Remarks
Yellowfin	1,443	8° 35′ N.-97° 32′ W.	2-2	83	Decapods	6 *Euphylax dovii.*
Yellowfin	1,220	8° 35′ N.-97° 32′ W.	2-2	8	Squid	Partly digested.
				9	Decapods	*E. dovii.*
				373	Fish	Vertebral remains.
Yellowfin	1,236	8° 02′ N.-96° 39′ W.	2-3	4	Squid	Partly digested.
				8	Fish	Partly digested.
				3	Decapods	*E. dovii.*
Yellowfin	1,072	7° 02′ N.-96° 39′ W.	2-3	12	Squid	Partly digested.
Yellowfin	1,449	5° 12′ N.-95° 36′ W.	2-4	0	None	Empty.
Bigeye	1,793	5° 12′ N.-95° 36′ W.	2-4	15	Squid	Partly digested.
				15	Decapods	*E. dovii.*
Bigeye	1,814	3° 06′ N.-95° 00′ W.	2-5	78	Squid	Remains of 3.
				18	Decapods	4 *E. dovii.*
Bigeye	1,507	0° 36′ S.-93° 14′ W.	2-8	89	Fish	Remains of 4.
				11	Decapods	*E. dovii.*
				1	Squid	1 squid pen.
Yellowfin	1,372	2° 36′ S.-93° 05′ W.	2-9	422	Fish	1 *Auxis* and other fish remains.
Yellowfin	1,607	2° 36′ S.-93° 05′ W.	2-9	113	Fish	Vertebral remains.
				7	Squid	2 beaks, 2 pens.
Bigeye	991	4° 28′ S.-92° 16′ W.	2-10	4	Fish	Vertebral remains.
Yellowfin	1,655	4° 28′ S.-92° 16′ W.	2-10	485	Fish	1 *Auxis.*
Yellowfin	1,710	0° 15′ N.-91° 20′ W.	2-13	586	Fish	2 *Auxis,* one partly digested.
Yellowfin	1,714	7° 18′ N.-86° 56′ W.	2-19	440	Decapods	25 *E. dovii*
				300	Fish	1 *Auxis.*
				11	Squid	Partly digested.
Bigeye	1,536	3° 16′ S.-84° 38′ W.	3-4	986	Squid	2 *Dosidicus gigas.*
				12	Decapods	*E. dovii.*

The examination of the stomach contents showed them to consist predominantly of fish, squid, and swimming crabs. Nine of the 15 stomachs contained fish and squid, and eight stomachs contained crabs. By volume, 57.8 percent of the total contents of the entire sample was fish; 27.2 percent, squid; and 15.0 percent, crabs.

The advanced state of digestion of many of the organisms precluded positive identification, but several specimens of the main food items were found almost intact, so these were used as reference to identify fragments of others of the same species. Four relatively undamaged frigate mackerel (*Auxis sp.*), from 300 to 330 mm. total length, were found in yellowfin tuna caught over a range of some 1,000 miles (Table 1), indicating that subsurface tunas and perhaps those inhabiting

surface waters as well, feed extensively on these smaller pelagic scombroids. Only two whole specimens of squid (*Dosidicus gigas*) were found, both taken from the same bigeye tuna. Almost whole swimming crabs were recovered from several tuna stomachs and were identified as *Euphylax dovii*, a portunid species. *Euphylax* is undoubtedly an important food item of the tunas, as shown by its frequency of occurence in stomachs. Supplementary information from logbooks of California-based tuna fishing vessels seems also to substantiate this observation.

No difference in food preferences of the yellowfin and bigeye tunas was noted, but the data are inconclusive. There is probably some seasonal variation in the foods of these tunas, but until such time as additional material is collected from the same region the extent of such variation will not be known.

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SEPARATION OF EGGS OF SYNENTOGNATH AND ALLOTRIOGNATH FISHES IN EARLY EMBRYONIC STAGES[1]

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The large, often pink or amber, eggs of allotriognath fishes (especially of the ribbonfishes, *Trachipterus* spp.) are occasionally taken in plankton samples in California waters. When these distinctive eggs are in advanced stages of development they are readily recognized as allotriognaths by the peculiar morphological characters of the embryo. In early developmental stages, however, these eggs can readily be confused with pelagic eggs of certain eastern Pacific synentognath fishes, especially the flyingfishes of the genus *Exocoetus*. Since *Exocoetus* sp. has been taken at least as far north as the Revillagigedo Islands, this genus is a part of the fauna with which California ichthyologists are concerned, and it is therefore desirable to record some basic differences in embryonic characters by means of which early stages of its eggs and those of allotriognath fishes can be distinguished.

Most of the described eggs of synentognath fishes bear filaments on the capsule, and are attached rather than free-floating (see especially Hubbs and Kampa, 1946). Such eggs are readily distinguished from those of the allotriognaths, for the latter have no filaments. Bruun (1935) found, however, that ovarian eggs of *Exocoetus volitans* and *E. obtusirostris* in the Atlantic are entirely devoid of filaments, and he suggested that they would prove to be pelagic. This is amply substantiated by material that is now available. Plankton samples taken on the "Shellback" cruise of Scripps Institution in the eastern Pacific in 1952 include eggs that are readily identified as *Exocoetus*. Many of them contain advanced embryos, some of them near hatching stage. Two species of *Exocoetus* are known to occur in the eastern Pacific (*volitans* and a form near *obtusirostris*). Whether the eggs in our collection are referable to more than one species has not yet been determined, but for the purposes of this paper it is adequate to treat these eggs simply as *Exocoetus* sp.

Eggs of allotriognath fishes are relatively large. Those that I have examined have a diameter of 2.5 to 3.0 mm. The transparent but commonly discolored (pink or amber) capsule is, in most of them, smooth and non-textured or is more or less striated. Eggs from the Mediterranean that Sanzo (1940) identified as *Lophotes* [=*Lophotus*] *cepedianus,* on the basis of the larvae that hatched from them, had a very finely sculptured capsule.

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The eggs of *Exocoetus* sp. from the "Shellback" expedition collections have a diameter of about 3 mm. The capsule is smooth and transparent, colorless or faintly pink, and completely lacks filaments, spines, or other modifications. Superficially, these eggs are therefore essentially similar to those of most known allotriognaths.

In early stages the embryos of *Exocoetus* and those of allotriognaths are much alike, especially in the large yolk sac, the absence of an oil globule, the proportions of the large bulging head and the long narrow body axis, the long gut that extends well back beyond the surface of the yolk sac, and the rather early development of the pectoral fin buds. In these early stages there are, however, already some distinct differences that forecast the great divergence of these two groups of fishes in their later embryonic development. In the allotriognath embryo the heart is in the typical chordate position, under the neck, and it remains in that position throughout embryonic development; in the synentognath embryo the heart is displaced forward onto the front of the yolk sac. In the allotriognath the tail tip remains in the simple, straight, embryonic condition; in the early synentognath embryo the tip of the notochordal axis enlarges and bends upward, the fin fold widens around it, and the definitive hypural and ray elements become large and well defined long before hatching. Allotriognath fishes, insofar as their early stages are known, are remarkable for the extreme elongation of one or more of the anterior dorsal rays in the advanced embryonic stages and in the larvae. This specialization is presaged in the early embryo by the precocious formation of a small knob-like enlargement on the mid-dorsal line in or slightly anterior to the pectoral region. No such structure develops in synentognath embryos.

These characters, summarized in Figure 1, should help to distinguish early embryos of these two orders of fishes, whether taken in plankton samples or from stomach contents.

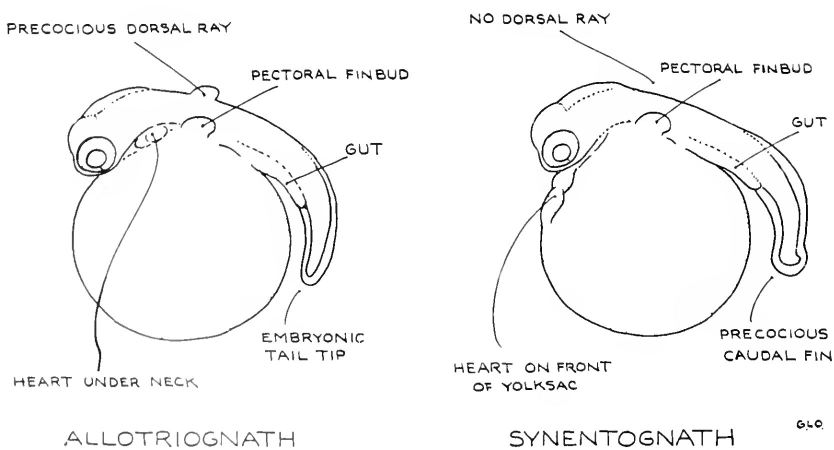

FIGURE 1. Diagrams of early embryonic characters of allotriognath and synentognath fishes (egg capsules and pigmentation omitted).

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AGE COMPOSITION OF THE SOUTHERN CALIFORNIA CATCH OF PACIFIC MACKEREL FOR THE 1953-54 SEASON[1]

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This is the fourth report on the age composition of the Pacific mackerel *(Pneumatophorus diego)* catch and covers the 1953-54 season, in which some 7⅗ million pounds of mackerel were landed in Southern California. The methods of sampling, age determination, and estimation of numbers of fish are the same as those used in the previous three reports, which covered the period 1939-40 through 1952-53. The catch of 7,613,000 pounds of Pacific mackerel during the 1953-54 season was the lowest total in 26 seasons or since 1928, when the Pacific mackerel first became prominent as a cannery species.

Table 1 presents the length frequency by age group for the mackerel from which otoliths were read during the 1953-54 season. Lengths of the fish are given in quarter centimeters. The 447 fish ranged in age from 0 through VI; of them, 324 or about three-fourths were younger than 24 months.

Table 2 presents the calculated number of fish landed for each age group, 0 through VI+, together with the percentage each comprises of the total number. Dependency of the fishery upon incoming year classes is particularly obvious. Of the total season's take, 82 percent was contributed by the 1953 hatch. The greatest previous percentage contribution by fish less than 12 months of age occurred during 1947-48, when the 1947 year class made up almost 20 percent. Of further interest is the fact that for five seasons, 1948-49 through 1952-53, two year classes (1947 and 1948) alone contributed between 75 and 90 percent of each season's bag. In the season just completed these two year classes yielded less than 5 percent of the 14,890,000 fish landed.

Table 3 shows the number, by year class, of fish landed for each age group 0 through V for the seasons 1939-40 through 1953-54, and Table 4 presents the same information in pounds. Although age groups I through VI+ made up only 17.8 percent of the 14,890,000 fish caught during the season (Table 2) they amounted to 42.8 percent of the 7,600,000 pounds.

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1953b. Age composition of the Southern California catch of Pacific mackerel for the 1952-53 season. Calif. Fish and Game, vol. 39, no. 4, p. 553-558.

[1] Submitted for publication September, 1954.

TABLE 1

Length of Fish in Quarter Centimeters at Each Age for the 1953-54 Season, Based on Otoliths Read

¼ cm.	Age group						
	O	I	II	III	IV	V	VI
75	--	--	--	--	--	--	--
76	--	--	--	--	--	--	--
77	--	--	--	--	-	--	--
78	1	--	--	--	--	--	--
79	1	-	--	--	--	--	--
80	--	--	--	--	--	--	--
81	--	--	--	--	--	--	--
82	1	--	--	--	--	--	--
83	3	--	--	--	--	--	--
84	10	--	--	--	--	--	--
85	17	--	--	--	--	--	--
86	6	--	--	--	--	--	--
87	2	--	--	--	--	--	--
88	11	--	--	--	--	--	--
89	10	--	--	--	--	--	--
90	16	--	--	--	--	--	--
91	12	--	--	--	--	--	--
92	8	--	--	--	--	--	--
93	12	--	--	--	--	--	--
94	13	--	--	--	--	--	--
95	6	--	--	--	--	--	--
96	14	--	--	--	--	--	--
97	13	--	--	--	--	--	--
98	5	-	--	--	--	--	--
99	12	--	--	--	--	--	--
100	11	1	--	--	--	--	--
101	15	--	--	--	--	--	--
102	10		--	--	--	--	--
103	8	--	--	--	--	--	--
104	7	--	--	--	--	--	--
105	13	--	--	--	--	--	--
106	8	1	--	--	--	--	--
107	3	1	--	--	--	--	--
108	4	2	-	--	--	--	--
109	8	1	--	--	--	--	--
110	1	2	--		--	--	--
111	1	4	--	--	--	--	--
112	5	7	--	-	--	--	--
113	-	2	--	--	--	--	--
114	1	2	--	--	--	--	--
115	--	6	--	-	--	-	--
116	1	2		--	--	--	-
117		2	1		--	--	-
118		4	1		--		--
119	1	2	--		--	--	--
120		4	1	-	--	--	--
121		1	1		--	--	--
122		2	2	-	--	--	--
123		1	1	-	--	--	--
124		1	3		--	--	--
125		-	3		--	--	--

TABLE 1—Continued

Length of Fish in Quarter Centimeters at Each Age for the 1953-54 Season, Based on Otoliths Read

¼ cm.	Age group						
	O	I	II	III	IV	V	VI
126	--	--	2	--	--	--	--
127	--	1	5	--	--	--	--
128	--	--	--	2	1	--	--
129	--	--	1	1	--	--	--
130	--	1	--	2	--	--	--
131	--	--	3	2	--	--	--
132	--	1	4	2	--	--	--
133	--	--	3	5	--	--	--
134	--	--	--	2	--	--	--
135	--	--	--	--	--	--	--
136	--	--	--	5	--	--	--
137	--	--	1	1	--	--	--
138	--	--	1	2	1	--	--
139	--	--	--	3	--	--	--
140	--	--	--	--	--	--	--
141	--	--	--	2	2	--	--
142	--	--	--	1	3	--	--
143	--	--	--	--	1	1	--
144	--	--	--	2	1	--	--
145	--	--	--	1	1	--	--
146	--	--	--	--	1	--	--
147	--	--	--	1	1	2	--
148	--	--	--	--	1	1	--
149	--	--	--	--	1	1	2
150	--	--	--	--	--	--	1
151	--	--	--	--	--	2	--
152	--	--	--	--	--	1	--
153	--	--	--	--	--	4	3
154	--	--	--	--	--	2	--
155	--	--	--	--	--	--	--
156	--	--	--	--	--	2	1
157	--	--	--	--	--	1	3
158	--	--	--	--	--	2	1
159	--	--	--	--	--	--	2
160	--	--	--	--	--	--	--
161	--	--	--	--	--	--	2
162	--	--	--	--	--	--	3
163	--	--	--	--	--	--	1
164	--	--	--	--	--	1	--
165	--	--	--	--	--	--	--
166	--	--	--	--	--	--	1
167	--	--	--	--	--	--	--
168	--	--	--	--	--	--	1
169	--	--	--	--	--	--	1
Totals	273	51	33	34	14	20	22

TABLE 2

Calculated Number of Fish Landed for Age Groups 0 Through VI+ for the 1953-54 Season—Percentages of Season's Contribution by Numbers and Year Class Are Also Indicated

	Age group							
	0	I	II	III	IV	V	VI+	Totals
Year class	1953	1952	1951	1950	1949	1948	----	----
Number of fish	12,237,000	676,000	475,000	583,000	161,000	367,000	391,000	14,890,000
Percentage of landing	82.2	4.5	3.2	3.9	1.1	2.5	2.6	100.0

TABLE 3

Number of Fish Landed by Year Class at Each Age Group from 0 Through V, 1939-40 Through 1953-54

Year class	Age group						Totals
	0	I	II	III	IV	V	
1934						5,340,000	
1935					10,570,000	1,443,000	
1936				35,130,000	13,551,000	970,000	
1937			26,540,000	25,261,000	5,121,000	822,000	
1938		25,200,000	69,322,000	25,661,000	5,271,000	1,082,000	*126,536,000
1939	2,960,000	20,793,000	26,454,000	12,698,000	7,133,000	1,616,000	71,654,000
1940	2,313,000	12,507,000	9,204,000	10,156,000	7,712,000	3,328,000	45,220,000
1941	398,000	29,376,000	54,106,000	33,905,000	10,312,000	2,294,000	130,391,000
1942	0	12,462,000	19,047,000	10,259,000	4,661,000	2,019,000	48,448,000
1943	836,000	16,556,000	10,327,000	11,872,000	5,087,000	429,000	45,107,000
1944	0	14,302,000	25,823,000	10,943,000	1,105,000	584,000	52,757,000
1945	556,000	9,330,000	7,980,000	756,000	688,000	72,000	19,382,000
1946	560,000	1,377,000	3,175,000	4,279,000	937,000	218,000	10,546,000
1947	7,181,000	63,330,000	49,255,000	15,826,000	11,127,000	2,756,000	149,475,000
1948	1,061,000	21,818,000	19,228,000	13,871,000	9,484,000	367,000	65,829,000
1949	136,000	3,854,000	4,428,000	1,286,000	161,000		9,865,000
1950	6,000	1,583,000	521,000	583,000			2,693,000
1951	769,000	46,000	475,000				1,290,000
1952	86,000	676,000					
1953	12,237,000						

* No information available on the 0 age group of the 1938 year class.

TABLE 4

Pounds of Fish Landed by Year Class at Each Age Group 0 Through V, 1939-40 Through 1953-54

Year class	Age group 0	I	II	III	IV	V	Totals
1934						6,851,000	
1935					12,141,000	1,885,000	
1936				31,946,000	14,592,000	1,414,000	
1937			19,306,000	22,163,000	7,015,000	1,478,000	
1938		11,578,000	19,762,000	27,249,000	6,651,000	1,499,000	*96,739,000
1939	961,000	11,609,000	21,747,000	12,898,000	9,058,000	2,334,000	58,607,000
1940	853,000	7,564,000	7,809,000	10,713,000	10,139,000	4,809,000	41,917,000
1941	116,000	15,085,000	40,066,000	36,527,000	13,595,000	3,236,000	108,625,000
1942	0	7,912,000	16,208,000	11,453,000	6,225,000	2,863,000	44,661,000
1943	274,000	9,991,000	9,221,000	12,786,000	6,718,000	638,000	39,628,000
1944	0	7,296,000	22,530,000	13,035,000	1,484,000	852,000	15,197,000
1945	158,000	5,627,000	7,601,000	867,000	899,000	100,000	15,252,000
1946	129,000	1,015,000	2,365,000	4,070,000	1,078,000	290,000	8,947,000
1947	1,477,000	29,643,000	32,320,000	14,692,000	12,819,000	4,058,000	95,009,000
1948	248,000	8,612,000	13,591,000	13,327,000	12,583,000	637,000	48,998,000
1949	47,000	2,155,000	3,547,000	1,509,000	229,000		7,487,000
1950	1,000	802,000	474,000	687,000			1,971,000
1951	252,000	34,000	483,000				769,000
1952	33,000	163,000					
1953	4,358,000						

* No information available on the 0 age group of the 1938 year class.

THE PHARYNGEAL POCKETS OF THE SARDINE, *SARDINOPS CAERULEA* (GIRARD)[1]

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Maizuru, Japan

The pharyngeal pockets of clupeoid fishes have been the subject of considerable inquiry and discussion by previous investigators.[2] The results of a careful analysis performed on the gizzard shad, *Dorosoma cepedianum* (Le Sueur), by Lagler and Kraatz (1045) indicated that the function of these pockets is accessory to the digestive processes rather than of a respiratory nature. The writer agreed with these conclusions in his recent study on the Japanese gizzard shad, *Konosirus punctatus* (Temminck and Schlegel), since in the pharyngeal pockets of the shad (1) the squamous epithelial lining is composed of nonvascular, striated cells, (2) a number of taste buds are recognizable in the epithelium, and (3) the internal lamellar structures appear to be modified gill rakers (Iwai, 1954). A comparison of the pharyngeal structures of the gizzard shad was made with those of adult California sardines taken off Gaviota, Southern California. The observations on the sardine reported below are based upon this comparison.

The writer is indebted to Professor K. Matsubara for his criticism of the manuscript, and wishes to thank Dr. Frances N. Clark of the California State Fisheries Laboratory for permission to work on these specimens and for reading the manuscript.

The sardine pharyngeal pockets lie on each side of the midline above the posterior region of the suprabranchial chamber. The organ, shaped roughly like a pocket, opens into the pharynx on the midline. It extends forward above the gills, forming a blind pouch at the anterior extremity (Figures 1 and 2), whereas in the gizzard shad, the anterior edge of the pocket turns to the proximal side (Lagler and Kraatz, 1945; Iwai, 1954).

Each pocket is supported by the fourth epibranchial bone expanded like the blade of a broadax, as described by Phillips (1942). In addition, a broad, cartilaginous extension, arising on the lateral edge of the expanded epibranchial and dividing into two parts, supports the lateral portion of the pocket. The dorsal edge of the pocket is attached to the ventrolateral border of the vertebral column and partly to the ventral border of the parasphenoid by loose fasciae.

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[1] Submitted for publication August, 1954.

[2] Biologists attempting to estimate the relation between sardine abundance and sources of food are faced with the possibility that these fish may obtain nourishment from nannoplankton or possibly dissolved nutrients in sea water. Clarification of this problem will require detailed knowledge of the anatomical features of the gill processes and of the alimentary tract. This paper constitutes a first contribution to such a study.—*Editor.*

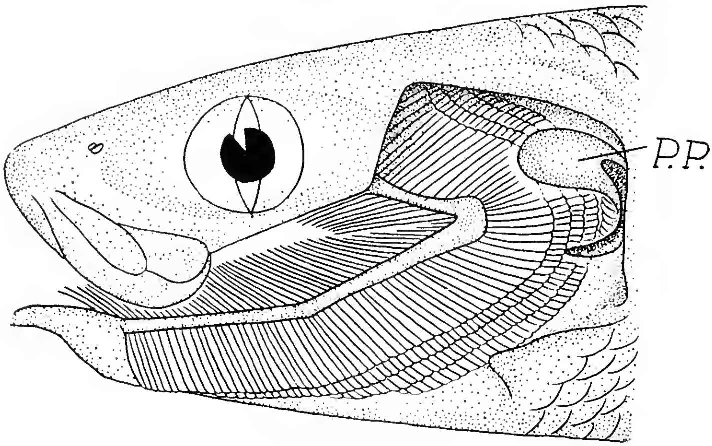

FIGURE 1. Head of an adult male sardine (220.5 mm. in standard length), showing the location of the left pharyngeal pocket (P.P.) The suspensorium and a part of the gill filaments are removed.

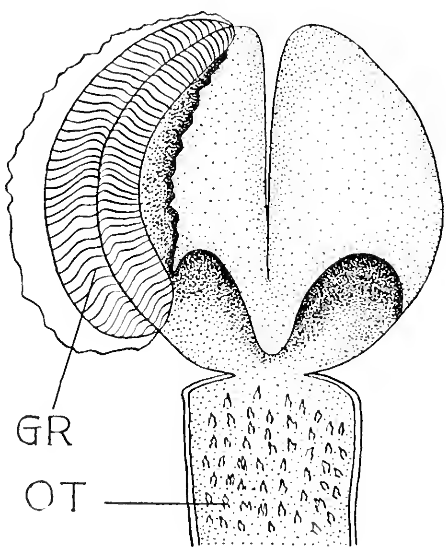

FIGURE 2. Diagrammatic ventral view of the pharyngeal pockets, showing their relation to the oesophagus. GR, modified gill rakers in the pocket. OT, oesophageal teeth in the anterior port of the oesophageal epithelium.

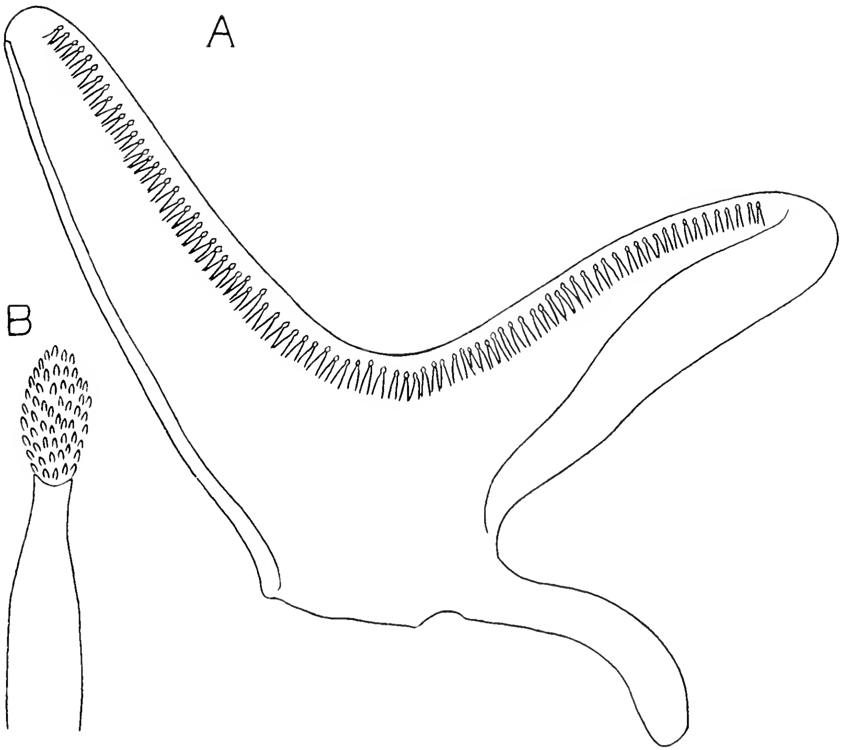

FIGURE 3. A modified gill raker in the pocket (A) and the spine-like process of the gill raker (B). It bears the spiny nodule at the distal end.

The lateral wall of the inner surface of the pocket is provided with two rows of numerous thin, flat, blade-like plates. Each plate possesses approximately 80 processes bearing spiny nodules at their tips (Figure 3, A and B). These become evident in staining with alizarin. Hubbs (1929) and Scofield (1934) attribute this structure to an adaptation to feeding habits. Based on the existence of these processes, it is suggested that the plate is a modified gill raker.

To study the histological structure of the pocket, the material was cut into 8-10 micron sections and stained with hematoxylin and eosin, or Mallory's triple stain. The inner surface of the pocket is lined with striated, squamous epithelium which contains a number of mucous cells and taste buds. These structures are virtually the same as those of the epithelium of the oral cavity and the pharynx. Under this lining lies loose connective tissue backed by a narrow longitudinal and a rather broad circular layer of smooth muscle. An histological study of these structures leads to the conclusion that this organ has no respiratory function nor has any edible food been observed therein. From the data here presented, it is not possible to determine the function of the pharyngeal pockets. However, if one must assign a function, the writer

would agree with Lagler and Kraatz's conclusion that through their elasticity they contribute to the concentration and swallowing of food.

These pharyngeal pockets have been observed in several clupeoid fish which feed chiefly upon such minute organisms as diatoms. The Japanese sardine, *Sardinops melanosticta* (Temminck and Schlegel) is similarly equipped.

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NOTES

RAINBOW TROUT SPAWN TWICE A YEAR

Rainbow trout (*Salmo gairdneri*), like other species of trout, normally spawn only once a year. Observations made by the writer at the Department's Darrah Springs Hatchery, Shasta County, California, indicate that some rainbow may spawn at intervals of approximately six months.

On July 6, 1951, 200 female rainbow trout were examined for the presence of "ripe" eggs. Ten of these had mature eggs suitable for artificial spawning and 18 had "water hardened" eggs which had recently passed their prime. The 10 fish with ripe eggs and five of the fish with water hardened eggs were tagged with metal jaw tags after being artificially stripped of their eggs.

All but three of these tagged fish had either died or lost their tags by January 1, 1952. On this date one fish was found to be ripe and was spawned. The other two females were spawned on January 6, 1952, exactly six months from the day on which they had first been spawned and tagged.

Most of the group of females from which the tagged fish were taken spawned in June, July, or August of 1951 and again around the first of January, 1952. It is of interest to note that the males did not become ripe in the summer, although they did ripen and produce sperm in the winter.

The fish of this group were 30 months old on July 6, 1951. They were of a strain of fall-spawning rainbow which had been brought into California from Idaho. The fall-spawning character had been developed by selection. It is not known to what extent the genetics of this strain is responsible for the peculiar spawning behavior, but it is assumed that the high temperature of the water is the primary factor. Temperatures in the brood-stock ponds at the Darrah Springs Hatchery range from 54 to 63 degrees F. Rainbow eggs produced at this hatchery have a relatively low fertility and an unusually high incidence of abnormal fry. This situation is also assumed to result from the high water temperatures.

Hot Creek fall-spawning rainbow also appear to spawn twice a year at Darrah Springs Hatchery, inasmuch as they, like the Idaho fall-spawning rainbows, contained masses of yellowish-brown eggs in addition to the viable ripe eggs when stripped in January. Over-retained eggs of a previous maturation are characteristically of this color and appearance.

When fish of the Idaho fall-spawning rainbow strain were transferred to Mt. Shasta Hatchery from Darrah Springs Hatchery they reverted to the normal spawning time (October through December) and spawned only once a year. Temperatures at the Mt. Shasta Hatchery range from 38 to 57 degrees F.—*Lloyd C. Hume, Inland Fisheries Branch, California Department of Fish and Game, September, 1951.*

THE PACIFIC LAMPREY, *ENTOSPHENUS TRIDENTATUS*, ABOVE COPCO DAM, SISKIYOU COUNTY, CALIFORNIA

The Pacific Lamprey, *Entosphenus tridentatus*, is normally an anadromous species that does not complete its life cycle without a period spent at sea. Recent observations above Copco Dam, forming a storage reservoir for the California-Oregon Power Company on the upper Klamath River, indicate an exception of interest.

Copco Lake, Siskiyou County, was formed by this 126-foot high dam in 1922. It is extremely doubtful that sea-run lampreys can ascend this dam, but a number of adult lampreys have recently been found in several Klamath River tributaries above the dam. The most interesting of these was taken from Copco Lake on June 5, 1953. It was attached to the inner surface of the mouth of a Klamath Small-scaled Sucker, *Catostomus rimiculus* (Figure 1). On April 14, 1954, two more adult lampreys, 8.55 and 7.63 inches in length, were collected from Lost River just below the Lost River Dam on Clear Lake, Modoc County.

FIGURE 1. A Pacific Lamprey from Copco Lake, Siskiyou County, attached to the inner surface of the mouth of a Klamath Small-scaled Sucker.

On June 6, 1954 another adult lamprey, 7.75 inches long, was taken from Beaver Creek, also a tributary of Copco Lake.

The probability is strong that these captures represent a landlocked form of the Pacific Lamprey. The existence of a landlocked race of *Entosphenus tridentatus ciliatus* in Goose Lake, Oregon, was recorded by Hubbs (Mich. Acad. Sci. Arts and Ltrs., Papers, vol. 4, 1924, p. 587-603).—*Millard Coots, Inland Fisheries Branch, California Department of Fish and Game, September, 1954.*

A COMMENT ON THE USE OF RED TAGS ON FISH

In various types of investigations on the behavior of fishes it is common practice to attach tags of different kinds and colors. Red tags are frequently used because they are noticed more easily than those of most other colors. Recent observations at the Department's Mt. Shasta Hatchery raise some doubt regarding the advisability of using red tags in some instances.

On May 28, 1954, the writers double-tagged several adult rainbow trout (*Salmo gairdneri*) with Petersen disks of both the flat and dished types held in place by stainless steel wire or monofilament nylon (Young et al., 1953). The tags were attached in the dorsal area, both just posterior to the head and under the anterior insertion of the dorsal fin. Some of the flat tags were red and the others were white, while the dished tags were yellow. The trout were returned to the hatchery broodstock holding ponds after being tagged.

A few days later it was noticed that other rainbow trout of the same age were attacking the red tags on one of the fish. This fish became weak and fungused and died on June 18th, three weeks after tagging. It was then found that another fish bearing red tags was being molested. This fish was removed for photographing just before it died on June 25th. No other attacks were observed. In the cases of these two fish it was noted that they were harassed only when they moved about the pond. While they were resting they did not appear to be struck, but as soon as they began to move other trout would come up from the rear and snap or strike at the red tags. Finally the skin would be torn and eventually the entire area around and between the tags would become an open wound (Figure 1).

Some of the fish with red tags were not attacked or were attacked so infrequently that no harm resulted. This could be due in part to the fact that after about a month algae began to grow on the tags and they became less conspicuous. It is suggested that "peck order" may be important. It is possible, though of course not proven, that the two fish killed by the attacks of their fellows were low in the peck order and that the other fish with red tags were not fatally attacked because they were high in the order. By the time the peck order shifted to other individuals the algae obscured the colors.

The first fish to be killed had three red tags and one white one. The second fish had two red tags on the left side and two white ones on the right. Only the red tags were seriously bothered. This is in agreement with the findings of Wolf and Wales (1953), who found that rainbow trout preferred red to several other colors. In the light of their findings it is not surprising that the red tags were attacked and

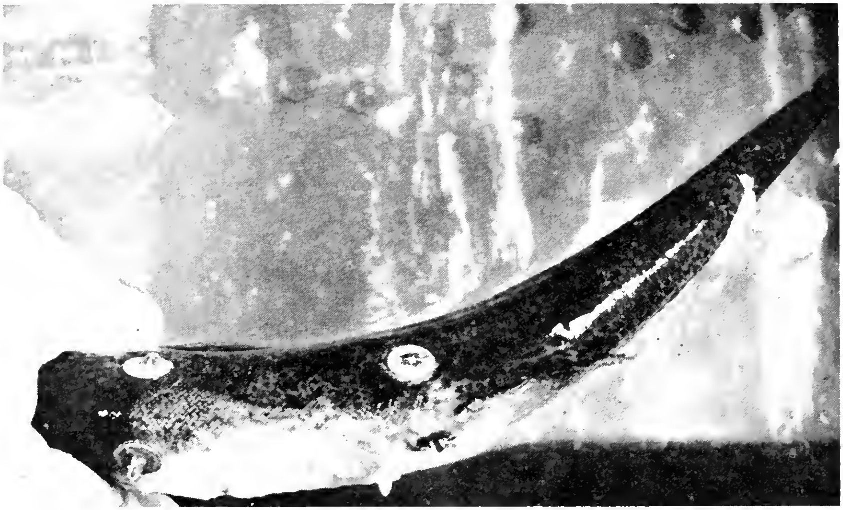

FIGURE 1. Dorsal view of trout double-tagged May 28, 1954, showing abraded area around red tags and unmolested area around white tags. *Photograph by E. R. German, June 25, 1954.*

is surprising that more fish with red tags were not injured. Further work is suggested to determine whether the peck order is an important factor.

These instances raise the question of whether or not red tags should be used. It cannot be concluded from these observations that other species of fishes will react as positively to red. It should also be pointed out that these fish were more crowded than in nature and were in very clear water, so that the tags were much more obvious than they would normally be. It is evident that despite these somewhat abnormal conditions the use of red tags may introduce a heretofore not considered mortality factor.

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E. R. German and D. A. LaFaunce, Inland Fisheries Branch, California Department of Fish and Game, September 1954. *This work was performed as part of Dingell-Johnson Project California F-7-R, "Sacramento-San Joaquin River Salmon and Steelhead Study," and F-8-R, "Trout Management Study," supported by Federal Aid to Fish Restoration funds.*

RETIREMENT

EDWARD L. MACAULAY

A 26-year-old chapter of outstanding service to the people of California, its hunters and fishermen, and its wildlife, has been concluded with the retirement in December of Edward L. Macaulay, Chief of the Wildlife Protection Branch of the Department of Fish and Game.

For three of those years Colonel Macaulay served as Executive Officer of the then Division of Fish and Game, and prior to that time was Chief of the old Bureau of Patrol.

His retirement as an administrator means that he will have more time to devote to the outdoor pursuits of camping, hunting, fishing and mountain climbing which he has followed all his life. Colonel Macaulay is known among outdoorsmen throughout the west as a top camp cook, and one who likes the back country which can be reached only by trail.

His career with the Division of Fish and Game began with his appointment as Chief of the Bureau of Patrol in January, 1929, and continued uninterrupted except for a tour of duty during World War II. After returning from the service, he was named Executive Officer of the Division in 1948, a position he held until its reorganization into a department in 1951. At that time he was named chief staff officer of the new Branch of Wildlife Protection.

Among the highlights of his career was his successful fight to maintain the patrol in adequate numbers during the depression, when reduced finances for a time threatened to decimate the force.

His military career also was marked with distinction. He commanded a field artillery battery in France during World War I as one of the youngest captains in the AEF. He rose to the rank of full colonel during World War II, and was in command at Dutch Harbor, Alaska, at the outbreak of hostilities in the Pacific. Colonel Macaulay also was active in the California National Guard, advancing from the ranks to major by the time the guard was called into federal service in 1940. At the time of his appointment to the Fish and Game post, Colonel Macaulay was serving with the Office of the Adjutant General of California. His other active military duty consisted of a tour with the National Guard during the San Francisco general strike of 1934.

His retirement to his home in Berkeley will leave a great void in the Wildlife Protection Branch, one of the keys to the Department's entire program. His energy and leadership, as well as his fine personal qualities which made him so many friends, will be sorely missed. But at the same time, we in the Department all wish him much happiness in his well-earned retirement, and know that he will continue his lifelong service to wildlife, even though no longer a member of the Department's staff.—*Seth Gordon, Director, California Department of Fish and Game.*

REVIEWS

All About Brook Trout, From Maine to California

By Bob Elliot; Practical Science Publishing Co., Inc., Orange, Conn., 1954; 242 p., illustrated by Wayne Buxton and the author. $2.95.

Originally published in 1950 under the title, "Eastern Brook Trout," this book was thoroughly reviewed by Herbert E. Pintler in "California Fish and Game" for October, 1950. The new edition has been revised so that it is more inclusive, and the price has been reduced from $5.

Now if you live in Maine, this is the book for you. Elliot provides records of all of its big brook trout, gives the best fishing times for individual lakes and streams, and lists its major squaretail waters. He also says a good deal about brooks in the other New England states, and in the Eastern Canadian provinces. However, there is comparatively little on the brook trout in other areas. Nine pages suffice to cover the rest of the United States. Only 13 lines (provided by our editor, incidentally) are assigned to this species in California. On the other hand, 3½ pages are devoted to a mere list of representative Maine waters, and the same number to lists of brook trout of over six pounds in weight taken in Maine since 1939.

However, what other state could provide such records? California produces thousands of brooks in its alpine lakes, but as fish managers have noticed, many of these seem to stop growing when about eight inches long. Elliot rarely mentions brook trout unless they are heavyweights.

He also discusses dry and wet fly fishing, rods and other equipment, and good flies. Much of this material is not specific for brook trout fishing, and is interspersed with information which is hardly pertinent; for example, a list of the woods used in trout rods and rod part nomenclature.

Elliot is obviously an enthusiast. He has searched the literature for references to brookies. Unfortunately, he has largely neglected any recent scientific work. He has documented the book so precisely that one is surprised at such omissions. One will learn virtually nothing of the life history of the brook trout here. A few quotations from a popular book by Jordan and Evermann in 1902 cover this phase.

There is a rather poor chapter on "The Romance of the Hatchery" and a better one on "The Future of the Trout . . ." There are 16 good black and white photos by the author, and three color plates by Buxton. Two of flies are only fair. The frontispiece of a male and female eastern brook in spawning coloration is excellent.

The book is well written and interesting. But don't expect it to contain all (there is) about brook trout.—*William A. Dill, California Department of Fish and Game.*

Sea-Birds

By James Fisher and R. M. Lockley; Houghton Mifflin Company, Boston, 1954; xvi+320 p., 9 col.+68 black and white photos and 55 text figs. $6.

The title of this volume, though misleading, is certainly brief yet descriptive and adequate and should meet with the approval of librarians everywhere. It is misleading only in that the book concerns specifically the North Atlantic. This minor imperfection is more than compensated by the finding in the 320 pages encompassed between the two covers of more facts and basic information on sea-birds than has been this reviewer's privilege to find in any similar tome. This in conjunction with superb photographs and some rather novel text figures and maps adds to its desirability for nature lovers, ornithologists, and students.

The first 177 pages include general information on sea-birds in the North Atlantic: structure; evolution; numbers and man; factors affecting numbers; movements; navigation; and social and sexual behavior. Since the year 1800, 111 species of primary and 32 of secondary sea-birds have been identified by competent observers at sea or on some shore in the North Atlantic. Of these, one primary sea-bird, the great auk, and one secondary sea-bird, the Labrador duck, are now extinct. Of the remainder, 82 primary and 30 secondary sea-birds actually nest, or have nested, on or near a North Atlantic or Mediterranean shore; two further species are purely inland breeders.

The second half of the volume concerns itself with the primary sea-birds, with a chapter devoted to each of the following categories: tubenoses, pelicans, skuas, gulls, terns and skimmers, and auks. Each chapter contains information on the distribution, habits and habitats, food and feeding, social and nesting behavior, and rearing of young, plus worlds of other interesting observations on and intimate glimpses into the lives of these sea-birds.

An appendix lists by scientific and common name the primary and secondary sea-birds of the North Atlantic. Their general distribution is also indicated. The appendix is followed by a very adequate biography, an index arranged in a systematic order of the vertebrate species mentioned in the text, and an index to authorities.—*John E. Fitch, California Department of Fish and Game.*

Wildlife Management, Volume II: Fur Bearers, Waterfowl and Fish

By Reuben Edward Trippenssee; McGraw-Hill Company, New York, 1953; xii+572 p., illus. $7.50.

This is the second and final volume of the author's current work on wildlife management. The text is divided into four sections entitled Foundations of Wildlife Production, Fur Bearers, Waterfowl, and Fish.

In the initial section, Foundations of Wildlife Production, the author discusses water and its conservation and marsh management. The discussion on water is highly dramatized and deals mainly with the problem of pollution. In the chapter on marsh and swamp management the author gives a description of the major types. Eastern conditions are described fairly completely, while western marshes are described very briefly. The aspects of mosquito control on marshes are discussed, as are agricultural drainage, water level controls, fire, etc.

The section on fur bearers devotes a chapter to each of the more important fur bearers or groups of fur bearers and predators. The author discusses laws relating to trapping and lists the general aims such laws should accomplish. The main recommendation for the management of fur bearers is limiting the trapping season to the time when the pelts are prime. The discussion on beaver brings out some aspects of beaver-trout relationships. In the chapter on coyotes the author praises the ability of the coyote to maintain itself under heavy odds and notes the damaging evidence against the animal with regard to its food habits. Nothing is said of the good coyotes may do, however. The write up on foxes concentrates on eastern conditions. The author suggests censusing red foxes and striped skunks by counting active dens on sample areas. There is a good chapter on muskrats, but no mention is made of diseases such as tularemia in the discussion on mortality in this species.

In the section on waterfowl the chapter on waterfowl ecology seems to be poorly organized and contains some questionable statements. Some of the data drawn upon seem out of date and the author fails to present a clear picture of the techniques used today in appraising waterfowl populations and production. The chapter on waterfowl management is interesting and well done, except in that it duplicates some of the previous chapter. Omitted in the discussion is the effect of sea gull predation on waterfowl production and the problem of getting an adequate harvest of all species of waterfowl without overshooting some species.

Interesting chapters on life histories of ducks, geese, and swans are included.

The section on fish and fisheries management includes data on both cold- and warmwater varieties and appears to be very well done.

To cover so broad a field in one volume, as the author attempts to do here, is understandably a Herculean task. It is natural that some omissions would be made and that difficulty would be experienced in organizing the material. It would be difficult for any one person to be expert on all of these facets and to remedy this to some extent the author asked other experts to write some sections. This practice has improved the text of the book but has also caused some duplication and further complicated organization of the material.

The text could have been polished to a greater degree, since small imperfections appear frequently. For instance, references cited are not always correct. As an example, five references to raccoons eating corn in California are given. On checking, one finds that only one of these has any bearing on California conditions.

In spite of some shortcomings the volume is well worth reading and will certainly broaden the outlook of the reader on the subject of wildlife management problems.—*A. W. Miller, California Department of Fish and Game.*

Animals of the Southwest Deserts

By George Olin; Southwestern Monuments Assoc., Globe, Arizona, 1954; 112 p., illustrated by Jerry C. Cannon. $1.

This is a popular account of the mammals of the southwest desert areas of the United States, including notes on identification, ranges, and natural history. Persons planning trips to the national parks and monuments of the southwestern states will find this booklet particularly useful.—*C. M. Ferrel, California Department of Fish and Game.*

The Duck Hunter's Manual

By Bob Kennedy; Hanover House, Garden City, N. Y., 1954; 96 p.; illustrated by Frank C. Jahn. $1.50.

This is a brief work written in popular style on the subject of duck hunting. The various kinds of ducks are illustrated by drawings which show the distinguishing markings to look for in making identifications. A number of decoy settings are discussed and illustrated by diagrammatic drawings. This manual is of pocket size designed for handy field use.—*C. M. Ferrel, California Department of Fish and Game.*

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